Trop. Med., 36 (4), 235−242, December, 1994

Japanese Encephalitis Vectors

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Abstract: On the ecological basis of vector mosquitoes of Japanese encephalitis, measures of their control were examined from viewpoint of their practicability. It was concluded that chemical control is not of practical value, biological control is of limited effectiveness, and environmental control by source reduction is impossible. Instead, it was recommended to improve human living style so as to reduce the frequency of man/mosquito contact.

Key words: Japanese encephalitis, vector, mosquito, control, *Culex tritaeniorhynchus*

It has been reported that Japanese encephalitis (JE) virus is transmitted by mosquito vectors such as *Culex fuscocephala, Cx. gelidus, Cx. pseudovishnui, Cx. tritaeniorhynchus*, and *Cx. vishnui*. Among them, *Cx. tritaeniorhynchus* is the most important throughout the areas where JE virus is distributed in East, Southeast and South Asia. Pigs are an important amplifier of JE virus. The virus is circulated between pigs and vector mosquitoes, and man is a dead-end host in that the infected man can not be a source of new infection.

Breeding place

The larvae of JE vectors including *Cx. tritaeniorhynchus* breed abundantly in rice fields, therefore their ecology is very much influenced by the practice of rice cultivation. But it is impossible to stop cultivating rice because of importance as a crop. The increase in number coincides with the time when the area of irrigated fields increases with rice cultivation. An example in Nagasaki is shown in Fig. 1. The same relation was demonstrated also in Sarawak (Hill, 1970) and Thailand. Thus, the epidemic of JE is closely related to the rice cultivation. Therefore, due consideration of JE is required when the development of rice fields is attempted, for example by deforestation. In fact, great epidemic of JE in recent years in Sri Lanka, Nepal and probably in Thailand is thought to be associated with the development of rice fields through deforestation.

Rice fields are sometimes very important as breeding sites of vector mosquitoes. Intermittent irrigation of rice fields is effective in controlling rice field mosquitoes, but complete irrigatioin system is not easy to be realized, thus application is limited.

Received for publication,
Contribution No. from the Institute of Tropical Medicine, Nagasaki University.

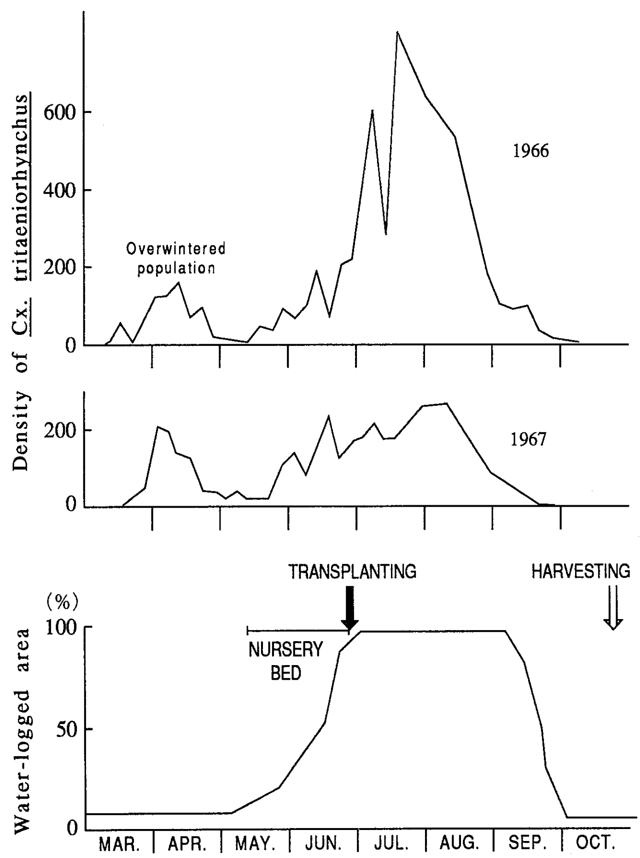

Fig. 1. Seasonal prevalence of *Culex tritaeniorhynchus* and water-logged surface area of rice fields in Nagasaki, Japan (after Wada, 1974).

Yearly change

In Japan, many JE cases were recorded every year in 1960s, and the number was more than 1,000 in 1966 and 1977. However, the number of cases declined remarkably and remained small after 1970, as shown in Fig. 2. This reduction in the number of JE cases was clearly associated with the decrease in the density of the mosquito vector, *Culex tritaeniorhynchus.*

Fig. 3 shows the abundance of adult *Cx. tritaeniorhynchus* examined in the Nagasaki area seasonally from 1965 to 1974. It was indicated that the population density decreased greatly in 1970s. Examinations of meteorological factors indicate that the difference in temperature and precipitation from year to year is not the reason for the recent reduction of the population density. One possible explanation is given by the change in the kind of agricultural insecticides applied to rice fields.

Natural enemies

From the amount of various agricultural insecticides used for rice pests in Nagasaki

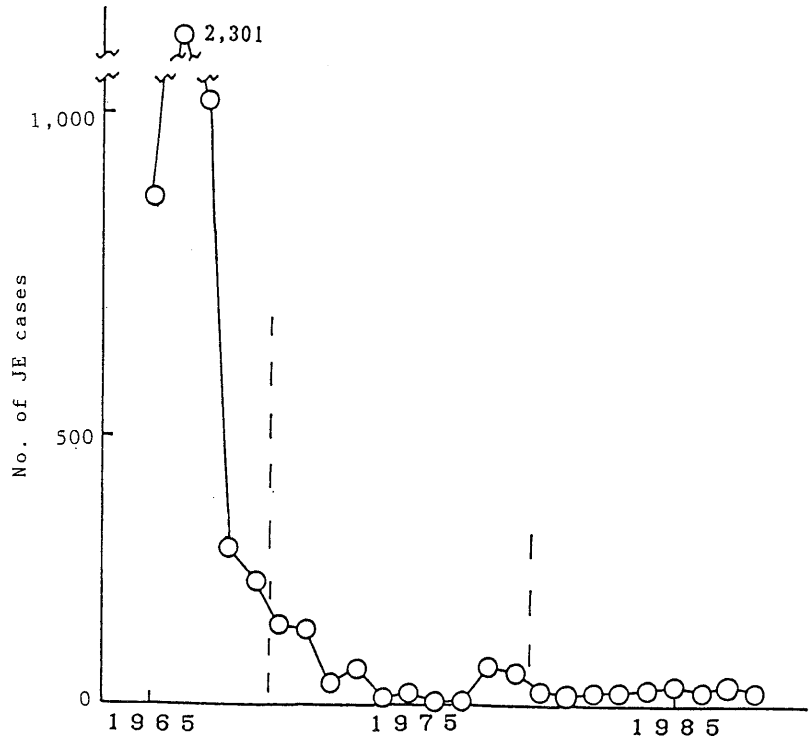

Fig. 2. Yearly change of JE cases in Japan.

prefecture, as given in Fig. 4, it is apparent that carbamate and organophosphorus (OP) insecticides increased recently, while HCH decreased. It was demonstrated that spiders are much more susceptible to HCH than to carbamate and OP insecticides, and the number of spiders greatly increased recently in the field. Spiders are very good natural enemies of adult mosquitoes. The increase of natural enemies of immature mosquitoes, such as of dragonfly and damselfly larvae and water beetles, has also been recognized. In view of the importance of natural enemies in controlling the mosquito density in the field, the switch of the kind of agricultural pesticides is perhaps a factor responsible for the recent decrease of *Cx. tritaeniorhynchus*.

It is no doubt that natural enemies play an important role in reducing the density of mosquitoes in nature, therefore it is advised to keep the environment favorable for the natural enemies.

Release of artificially cultured natural enemies is not of operational value in most cases due to much cost needed and insufficient effectiveness. Introduction of natural enemies into new areas has not been successful in controlling mosquitoes so far attempted. It was found that the introduction of *Gambusia affinis* to some parts of Japan almost completely drove away a native fish, *Oryzias latipes,* with similar ecological requirements in rice fields, so that the introduction of *Gambusia* did not help the control of mosquitoes at all.

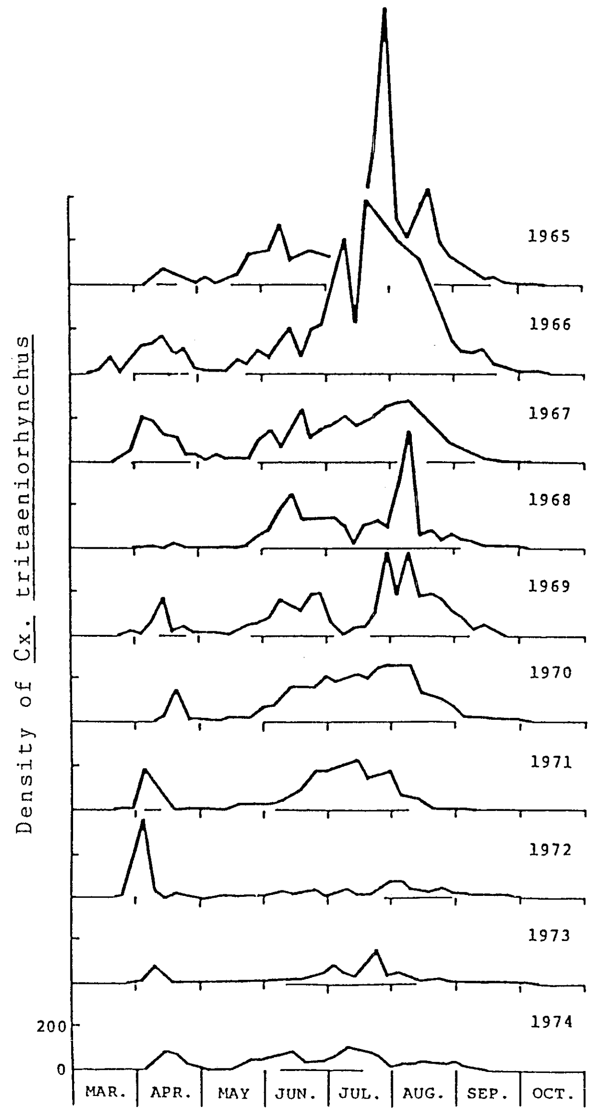

Fig. 3. Seasonal prevalence of *Culex tritaeniorhynchus* from 1965 to 1974 in Nagasaki, Japan (after Wada *et al.,* 1975; data added).

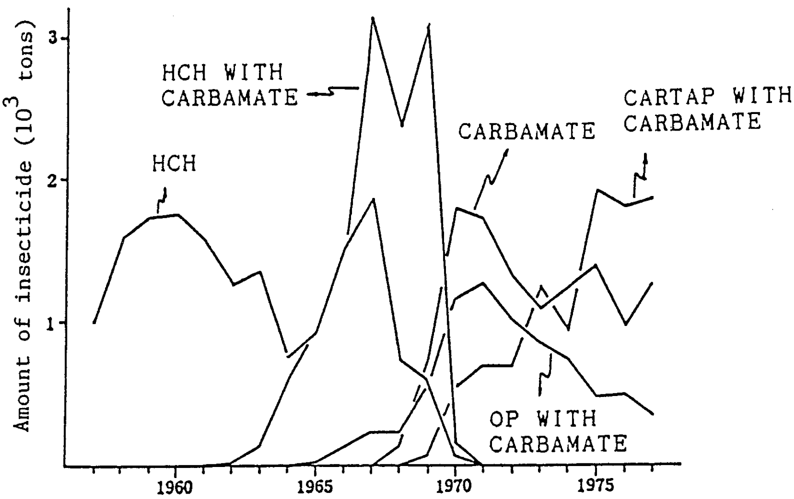

Fig. 4. Amounts of insecticides sprayed in rice fields in Nagasaki, Japan (after Mogi, 1978).

Dispersal

Cx. tritaeniorhynchus has the great dispersal ability. This was studied by a mark-recapture method in a rather hilly area of Nagasaki (Wada *et al.,* 1969). Female mosquitoes differently marked with fluorescent dyes were released from 3 points, and recapture catches were made by light traps at 19 points in 7 nights. The results showed that the usual flight range was about 1km and the maximum flight distance covered was 8.4km. Owing to this great flight ability, insecticide spray only around dwelling houses is not enough to protect humans from JE infection.

Chemical control

Various methods of chemical control for *Cx. tritaeniorhynchus* were tested in the field and in the laboratory in Japan and other countries. For example, Nishigaki (1970) studied the change in number of *Cx. tritaeniorhynchus* females after the residual spray with malathion (OP) and fenthion (OP) onto inside walls of all animal sheds and dwellings, and found that the number of females decreased just after the spray, but increased soon after. In contrast to the case of some malaria vectors, the residual spray is rather ineffective to suppress the population of *Cx. tritaeniorhynchus*. This is probably due to the exophilic habit of this mosquito.

On the other hand, the anti-larval application of insecticides to rice fields, which are the main breeding place of *Cx. tritaeniorhynchus* and other JE vectors, is effective to suppress the mosquito population, but only for one or two weeks in usual cases. This means that if we wish to keep the mosquito population density low enough to interrupt the transmission of JE throughout the epidemic season, at least several applications would be necessary. It will cost too much to control JE vectors by larviciding, because they breed in the vast area of rice fields. Farmers are not willing to pay the cost of insecticide spray against mosquitoes, because it does not help to increase the yield of rice.

The idea of suppressing a population of *Cx. tritaeniorhynchus* at the beginning of mosquito breeding, when the density is usually low, does not seem to be of operational value. Nishigaki (1970) applied a larvicide weekly from early spring to all possible breeding places of *Cx. tritaeniorhynchus* in a village, and the larval density could be kept very low until the stop of larvicide application, but the recovery of the population thereafter was very quick. Considering that every possible effort was exerted to spray the larvicide effectively, it is apparent that the beforehand control of the population is rather discouraging.

Insecticide resistance

The chemical control of *Cx. tritaeniorhynchus* became more difficult due to the development of insecticide resistance. It seems that agricultural insecticides sprayed against rice plant pests had been very effective also to control this mosquito until the middle of 1970s. However, *Cx. tritaeniorhynchus* collected in 1984 from many localities in Japan all showed surprisingly high resistance to several organophosphorous and carbamate insecticides (Yasutomi & Takahashi, 1987). It can be said that the high resistance to these insecticides in *Cx. tritaeniorhynchus* was caused apparently by agricultural chemicals, since insecticides were never used in a large scale against rice field breeding mosquitoes. This strongly suggests that there is a possibility of the development of insecticide resistance in rice field mosquitoes wherever agricultural insecticides are used.

Light traps

Mosquito control by using light traps has been a great concern of entomologists (Wada, 1974, 1988; Mogi, 1978). The trap set at pigsties attracts and kills many JE vectors including engorged and infected ones, while their natural enemies are much less affected. However, the efficiency of the light trap in collecting mosquitoes was revealed to be so low that strong impact on the vector population is hardly expected.

Mosquito contact

Hundreds of JE cases were recorded annually in Japan in 1960s, but the number decreased to tens or less in 1970s. During these periods, there was a clear positive relation between the number of JE cases and the density of vector mosquitoes, as shown in Fig. 5. Similar relation was observed also in Kyoto (Maeda *et al.,* 1978). There was, however, no appreciable increase in the number of JE cases in 1980s and onward, despite the increase of vector mosquitoes by the development of insecticide resistance. This discrepancy between the number of JE cases and the density of vectors seems to be due to the improvement of human living style and the movement of pigsties to areas far from rice fields during 1970s, thus reducing mosquito contacts with man and pigs. Many pigsties were found near rice fields in 1960s when great epidemic was occurring, but they are now located mostly far from rice fields in Japan.

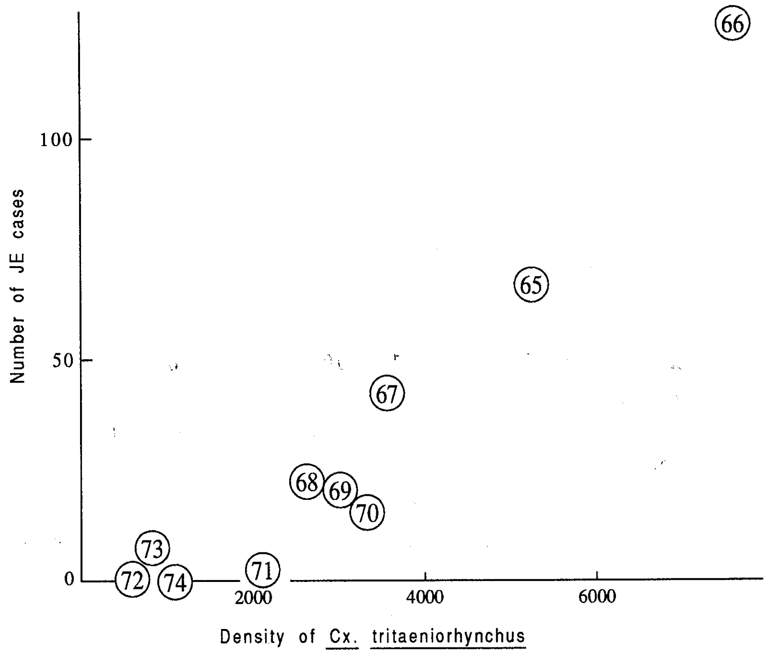

Fig. 5. Relation of the number of JE cases to the density of *Cx. tritaeniorhynchus* in 1965–1974 in Nagasaki, Japan (after Wada *et al.,* 1975; data added).

In the control of JE, reduction of mosquito contacts with man and pigs should be taken into serious consideration. This could be done, for example, by air-conditioning the house and by using the mosquito net and screen with or without insecticide impregnation. It is also advised that human dwellings and pigsties be settled at a far distance from rice fields where JE vectors breed.

Conclusion

It is clear from the above that the control of the vector mosquito of JE is very difficult. Chemical control needs too much costs or is not effective, biological control is of limited effectiveness, and environmental control by source reduction is impossible. Therefore, there are no other ways than protecting ourselves from mosquito bites. The living style of humans should be improved so as to reduce the frequency of man/mosquito contact. Education would certainly play a very important role in the improvement of living style. Vaccination should have the first priority for the control of JE.

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