기 생 충 학 잡 지 제29권 제 1 호
The Korean Journal of Parasitology
Vol. 29, No. 1, 67-85, March 1991

Epidemio-entomological survey of Japanese encephalitis in Korea*

Doo-Hyun Baik and Chong-Yoon Joo

Department of Parasitology, School of Medicine, Keimyung University, Taegu 700-310, Korea

Abstract: In order to determine the seasonal prevalence and population dynamics of *Culex tritaeniorhynchus* in relation to the epidemics of Japanese encephalitis, and ecology of these vector mosquito in Kyungpook Province, Korea, studies were conducted during the period of 7 years from 1984 to 1990.

Cx. tritaeniorhynchus first collected in June between 4th and 28th, and trapped in large numbers during the period from mid-August to early September, showed a simple sharply pointed one-peaked curve. There was a gradual decrease from mid-September, with a very small number of them collected until early October in every year. The average number of *Cx. tritaeniorhynchus* rapidly decreased after 1985, and the number became particularly low in 1989. The highest population density, which was observed in August during the initial three years, was found to be delayed in the following years, accompanied by a decrease in the number of mosquitoes.

In the trend of nocturnal activity of *Cx. tritaeniorhynchus*, with oncoming darkness they become very active, gradually decreasing in activity toward mid night, but slightly increasing toward dawn. The immature stages of *Cx. tritaeniorhynchus* were first found in rice fields contributing to peak adult densities in mid-July. The highest average densities of *Cx. tritaeniorhynchus* was 14,900 per m^2 on mid-August 19th.

The larval *Cx. tritaeniorhynchus* showed high resistance levels and resistance ratios against 5 organophosphorus compounds. In the adult horizontal life table characteristics of Kyungsan colonies of *Cx. tritaeniorhynchus* under insectary conditions, life expectancy was 28.3 days for males and 59.8 days for females. The net reproductive rate was 7.8 and generation time was 25.6 days.

Key words: *Culex tritaeniorhynchus*, Japanese encephalitis, seasonal prevalence, population dynamics, Kyungpook Province

INTRODUCTION

Japanese encephalitis (JE) is one of serious arbovirus infections in human beings, with high mortality in eastern Siberia, China, Korea, Taiwan, Japan, Malaya, Vietnam, Thailand, Singapore, Guam and India, transmitted by mosquitoes. *Cx. tritaeniorhynchus* is the most important one in the JE epidemic areas. The initial report on the existence of autochthonous cases of JE in Korea was made by Sabin *et al.* (1947) for the first time by isolating the virus of the disease among the American soldiers in Kunsan area. They also proved the presence of antibody of JE in Korean residents from several

* Presented at the 32th annual meeting (1990) of The Korean Society for Parasitology.

areas, including Kunsan. Although a few cases of encephalitis lethargica had been found as early as the 1930s by Japanese workers in Korea (Morinaka and Ohnaka, 1926; Yoshihara, 1932; Takai, 1933; Shiba and Chun, 1936), it was considered to be due to misdiagnosis as JE.

Since the occurrence of a large nationwide epidemic in 1949, epidemiological, virological and immunological studies on JE and its vector mosquitoes have been carried out extensively by many investigators, recognizing the urgency of the problem. Kono and Kim (1969) summarized the epidemiological features on JE in Korea from 1949 to 1966; Lee *et al.* (1969) studied JE virus isolation from mosquitoes of Korea; Shin *et al.* (1971) reported on the seasonal prevalence of mosquitoes throughout the country, with particular reference to JE vector mosquitoes.

After the begining of the New Village movement in the third "Five-year Economic Plan" in 1972, the Korean government established a plan to expand the land by cultivating hilly areas, thus practicing land reclamation, and also accompanied the establishment of an irrigation system, reformation of land, improvement of agricultural technique, and intensive use of agricultural chemicals. Accordingly, increased rice production inevitably resulted in the expansion of mosquito larval habitats, and introduced important changes in the agroecosystems which determined the distribution and abundance of mosquitoes (Sturtees, 1970; and Mogi, 1984).

Recently, Joo and Wada (1985) studied the seasonal prevalence of the vector mosquitoes of JE in Kyungpook Province, and Kim (1986) reported that the annual disease cases in 1982 were unusually high, a total of 1, 197 with a mortality rate of 3. 1. Every year a few cases of JE have been reported in Korea. However, few reports on epidemio-entomological survey have been available. The present paper summarizes the data on seasonal variation and population density of adult and larval mosquitoes collected from Kyungpook Province, from 1984 to 1990, and on the numbers of reported cases of JE during that period.

GEOGRAPHICAL CONDITIONS OF SURVEYED AREAS

Kyungpook Province is situated in the southeast part of the Korea peninsula, having an area of 19, 700 square kilometers, and is bordered on the northeast by the Sobaek range branches of Mt. Taebaek and runs from northeast to southwest along the border of Kangweon, Chungpook, and Jeonpook Provinces. In the south near the border of Kyungnam Province there are many mountains, such as Mt. Biseol, Mt. Unmoon, Mt. Moonbok, and Mt. Koryun, arranged in a circle that make the Province seem to be a big hollow.

Two areas in Kyungpook Province were selected as present survey stations (Fig. 1). Keimyung University training farm in Kyungsan county of the Province was the main study area. It is located about 15 kilometers E.S.E of Taegu city, situated on a low hill studded with copse, orchards, small rice fields and small swamps. The farm covers an area of approximately 250, 000 square meters and consists of pasture, animal shelters, vinyl houses, and human dwellings. Large numbers of cattle, pigs, fowls, dogs, sheep, and deer are raised in this farm but there are no wild animals which could be important as hosts of vector mosquitoes.

Another areas selected for this study was the Agricultural research farm in Kyungpook Provincial office of Rural development. It is located in Dongho village, a northern district of Taegu city. The total area of rice field in this station was about 150, 000 square meters. The north and west corners of the rice field contain the house-dwellings and the east borderline is limited in the foothills of a low mountain range.

The rice field irrigation begins in May and ends in late August or early September: during this period the rice fields form the main breeding places for the vector mosquitoes. The domestic

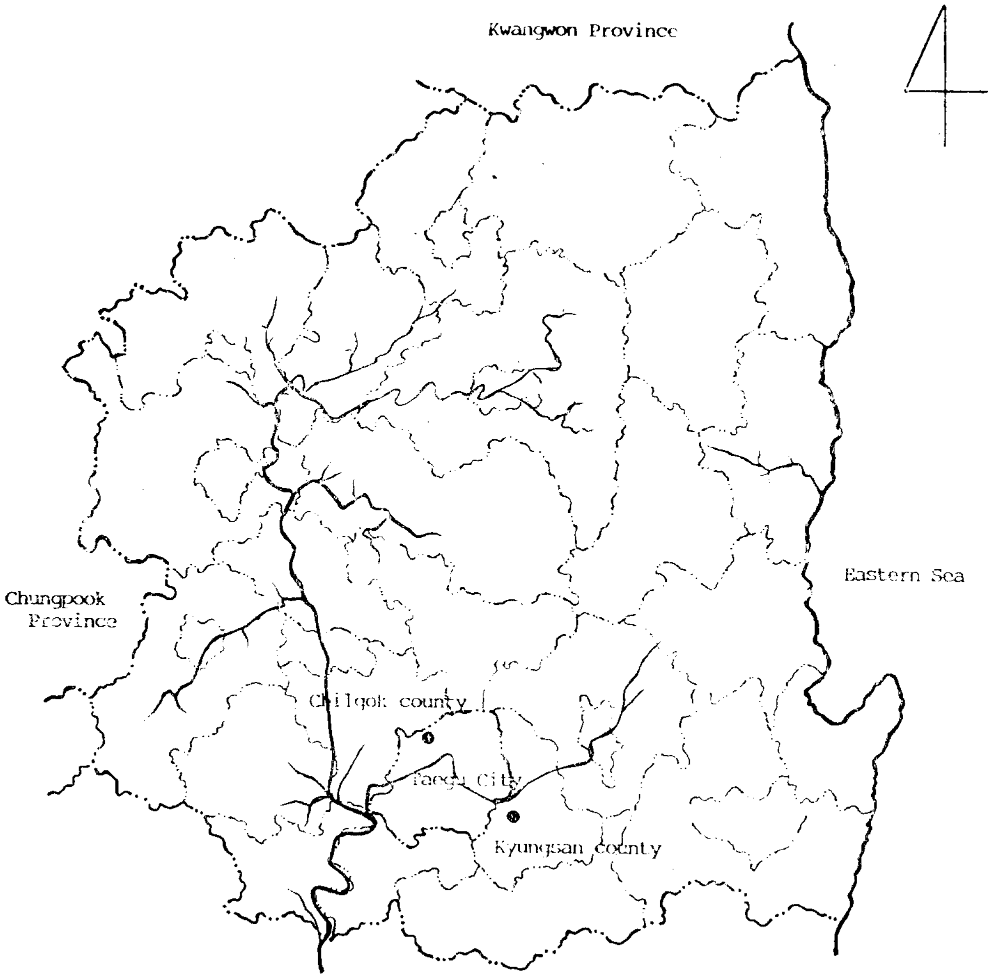

Fig. 1. Surveyed areas (•) in Kyungpook Province, Korea.

animals are cows, pigs, dogs, and chicken, etc. The cow-shed is usually one compartment of the house-dwelling and piggery is nearby but separated from the house and is sometimes within the garden. The hen-house may be in the garden or inside the cow-shed with the cows. The dogs have no kennels but are kept by the houses, usually in the space under the floor.

The study areas are under the influence of a typical continental climate of the eastern coast affected by both high atmospheric pressure from the cold continent and a low one from the Pacific Ocean in the summer season. Therefore, seasonal fluctuation of air temperature and precipitation, which is of fundamental importance to understand the dynamics of mosquito populations, is very great. Meteorological data in this study are based on monthly reports of the Taegu branch of The Korea Meteorological Agency during the period from 1984 to 1990 (Table 1).

MATERIALS AND METHODS

Light trap operation: In order to observe the seasonal fluctuation of JE vector mosquitoes, light trap collections were conducted as follows: A light trap was fixed at 1.5 m above the ground at trapping spots, the piggery A, cow-stall B, and the human dwelling C, and operated from dusk to dawn on one-night per week

Table 1. Monthly maximum and minimum temperature, relative humidity, and total precipitation reported by regional Meteorological Center in Taegu, Korea during 1984 and 1990

		1984	1985	1986	1987	1988	1989	1990
January	T*:	−11.1~11.3	−12.8~9.5	−12.0~11.4	−10.7~11.7	−9.2~11.6	−9.4~12.5	−11.5~10.8
	H**:	33~58	35~60	35~62	14~58	19~54	23~66	39~56
	P***:	0	0	0.9	44.4	12.6	110.7	22.3
February	T:	−12.4~13.3	−7.9~13.4	−8.5~15.0	−9.9~19.6	−9.9~14.1	−5.9~17.1	−2.3~22.1
	H:	30~57	35~68	33~62	20~58	19~56	22~64	38~58
	P:	8.0	21.3	20.4	43.9	2.9	90.5	45.3
March	T:	−7.3~23.0	−4.0~17.6	−4.5~20.4	−4.3~20.3	−5.0~19.5	−3.9~22.1	−3.8~12.9
	H:	29~59	37~67	33~68	24~59	21~58	19~60	52~70
	P:	12.2	72.1	51.6	51.4	45.2	100.4	85.5
April	T:	−1.2~27.0	0.6~28.6	2.4~28.1	0.9~27.9	3.7~30.4	3.5~28.2	2.7~27.3
	H:	28~69	34~64	22~56	19~56	19~53	19~56	38~58
	P:	136.5	70.2	34.8	42.7	49.6	34.1	90.5
May	T:	7.4~31.2	7.7~30.0	8.7~31.0	7.2~30.8	7.7~32.0	9.5~32.7	8.9~30.8
	H:	31~64	34~69	25~61	19~63	17~60	24~64	44~65
	P:	41.3	105.7	97.4	62.3	64.1	46.3	143.1
June	T:	14.4~32.7	12.5~32.0	11.5~32.5	10.6~36.3	14.4~35.1	12.6~32.9	10.0~33.0
	H:	35~73	41~76	28~74	21~66	26~71	25~70	53~70
	P:	165.9	167.3	226.9	138.7	85.9	103.3	200.5
July	T:	19.2~34.9	18.7~36.8	15.7~35.3	18.0~34.8	15.4~38.0	15.2~35.5	10.0~35.3
	H:	46~77	55~80	44~79	33~77	43~79	23~79	66~75
	P:	341.8	186.8	136.0	275.7	215.1	306.6	251.3
August	T:	21.0~38.1	22.0~37.7	18.2~36.6	18.7~32.5	16.1~36.5	18.5~35.4	13.1~38.5
	H:	42~75	41~79	41~76	49~82	42~76	35~72	57~70
	P:	206.0	338.4	178.4	327.2	74.5	149.8	125.9
September	T:	12.6~31.4	9.4~33.8	8.4~31.4	8.9~31.5	11.7~32.3	11.8~30.1	11.5~33.2
	H:	45~77	43~79	27~74	24~71	36~74	28~77	54~74
	P:	205.8	262.0	123.4	11.0	52.7	196.4	197.0
October	T:	1.9~25.7	5.7~26.5	−0.7~24.5	2.5~29.9	2.1~28.0	1.6~25.9	4.2~26.6
	H:	38~68	36~74	28~70	21~64	22~61	19~66	53~69
	P:	14.9	124.0	78.6	44.6	3.9	18.8	13.9
November	T:	−4.6~23.8	−1.9~19.9	−4.9~19.9	−5.0~22.2	−1.7~21.7	−2.1~21.3	−1.3~23.7
	H:	35~72	37~71	22~59	15~63	19~53	16~64	39~56
	P:	52.6	37.0	10.6	51.8	3.4	61.9	43.5
December	T:	−9.5~15.4	−10.2~16.0	−7.1~16.0	−8.8~20.1	−8.0~17.4	−5.1~19.3	
	H:	38~68	36~67	23~65	17~56	23~59	10~64	
	P:	3.5	11.8	34.8	0.4	7.1	28.6	

* T: temperature(°C) ** H: relative humidity(%) *** P: precipitation(mm)

schedules. Mosquitoes collected at each station were counted by species.

Indices of mosquito abundance: In order to compare the annual abundance of *Cx. tritaeniorhynchus*, mean percent index(MPI) which was proposed by Maeda *et al.*(1978), was used. MPI is calculated by the following procedure. If the total number of mosquitoes caught by *m-time* collections at a station of i in a year of k is given by $Xik=\sum_{j=1}^{n} Xijk$, where $Xijk$ is the number of mosquitoes caught in each collection, MPI is shown in the following equation: $MPIk=\frac{100}{n}\sum_{i=1}^{h}(Xik/Xio)$, where n is the number of station and Xio is the total number of mosquitoes caught at each station in 1986, when the stations for collection were being fixed. Seasonal prevalence can be also expressed by MPI from the data of light trap collections as follows: $\mathrm{MPI}jk = \frac{\mathrm{MPI}k}{n} \sum_{i=1}^{n} (\mathrm{X}ijk/\mathrm{X}ik)$.

Human baited trap: In order to determine the relative numbers and species of mosquito which were attracted by human beings, human baited trap was performed as follows: A man was allowed to lie on the floor of a tent of 2.6×2.0 m size and 1.5 m in height. A open window of 2.0×1.5 m permitted entry of mosquitoes. All mosquitoes biting or attempting to bite were collected between 19:00 and 06:00 hours on one-night in July and August in 1990.

Collection of resting mosquitoes: In order to determine the resting places of mosquitoes in day-time, oral aspirators, and hand nets, about 40 cm in diameter, were used to catch adult mosquitoes resting in the human and animal shelters. The census of adult populations was done from 1984 to 1990, and a part of the results were published already (Joo and Wada, 1985).

Larval collection: In order to estimate the density of mosquito larvae and pupae, 30 fixed rice fields were dipped from April to October at one-week interval during the period from June 15 to August 30 in 1990. The dipper was 15 cm in diameter and 5 cm in depth with a wooden handle of 60 cm in length.

At the outset a collector stood at a point on the side of rice field, and took a dip on the water surface, which was thought to be most favorable for the breeding of the larvae and pupae within the reach of the dipper. In each rice field, the dipping was made ten times which were thought to be necessary to determine the distribution pattern of the numbers of *Cx. tritaeniorhynchus* larvae in a rice field (Wada *et al.*, 1971). The efficiency of the dipper to collect *Cx. tritaeniorhynchus* was examined, and one larva and/or pupae per dip by the dipper proved to be equivalent to 186 larvae and/or pupae per m^2 of the water surface of rice fields (Wada and Mogi, 1974). Total No. in the study area=average No. per dip×186×total area with water in m^2.

Resistance level for OP compounds: In order to determine the insecticidal resistance, blood-fed females of *Cx. tritaeniorhynchus* were collected from human and animal shelters with an insect net or sucking tube, and transferred into the cages. The mosquitoes were allowed to oviposit in an insectary at 30±1°C and of 70~80% relative humidity with 16 hours of illumination per day. Approximately 300 first instar were reared in enamel pans measuring 50×40 cm filled to 2 cm depth of water and fed on crushed powders of laboratory mouse pellets and the adults were fed on 5% sugar solution. Insecticidal resistance was modified from those described by Takahashi and Yasutomi (1987). Toxicities of five organophosphorus were determined with fourth instar. Lc 50 values were calculated from the average of two replicates.

From these data the regression of the probit mortality on log dosage was computed and the Lc 50 were obtained.

Life table characteristics of *Cx. tritaeniorhynchus*: In order to estimate the effects of mating and/or male-female association on the lifespan of adult *Cx. tritaeniorhynchus*, the longevity of adults were tested by comparing six groups of males and females. All experiments were replicated two times and conducted in an insectary in which the temperature 27±1°C and relative humidity was regulated between 75±5%. A 16L:8D photoperiod was established with 40 watt fluorescent light, and with 1.0 hour simulated dusk and dawn (Joo *et al.*, 1988). Adults were continuously offerred 5.0% sucrose solution in flask with cotton wads and changed to new solutions every 5 days.

Each morning all dead individuals and egg rafts were removed and recorded. The calculation procedures, formulae, and rationale used in the present study was made according to the methods described by Reisen *et al.* (1979) as follows:

1. Age specific survivorship, $Ix = Yx/Yo$,

where Yx is the number of males alive on each day, x.

2. Age specific life expectancy, $e_x = Tx/Ix$, where $Tx = \sum_{x=x}^{w} Lx$ and $Lx = (Ix + I_{x+1})/2$ with w=the day the last individual died.

3. Age of mean cohort reproduction, $To = a \sum_{x=1}^{w} I_x m_x X/Ro$ starting at $x=1$, the day of adult emergence, and R_0=net reproductive rate per cohort.

4. The innate rate of increase (r_m), $I = a \sum_{x=1}^{w} I_x m_x e^{-r} m^{(x+d)}$ and e is the base of natural logarithms and d is the length of time from oviposition in the present generation to first oviposition in the offspring generation. a is the proportion of female that survive from the egg through adult emergence, and m_x is the mean number of female progeny produced by a female of age, x, and x is the age interval.

5. Mean generation time, $G = \ln Ro/r_m$, G was a more realistic estimate of generation time which included the larval stages and the nulliparous adult period, i.e., the time from oviposition to oviposition.

Incidence of JE patients: In order to determine the incidence of JE patients, data were taken from the official reports by the Ministry of Health and Social Affairs, Republic of Korea. The JE patients referred were confined to the cases with serological confirmation and/or successful isolation of JE virus from autopsied specimen.

RESULTS

Table 2 shows the seven years' observation of the earliest days when *Cx. tritaeniorhynchus* began to be collected by light traps and air temperature and humidity at that time in Kyungsan county, Kyungpook Province. *Cx. tritaeniorhynchus* began to be collected in June between the 4th and 28th. At that time the air temperature ranged from 12 to 35.1°C and humidity from 65 to 90%. The average number of *Cx. tritaeniorhynchus* per trap-night was from 0.3 to 2.5.

Table 2. Seven years' observation of the earliest date when *Cx. tritaeniorhynchus* appeared in Kyungsan county, Kyungpook Province, together with meteorological data

Year	Earliest date*	Temp. (°C)	Humidity (%)	Average No./trap-night
1984	June 19	21.9～29.4	77	2.5(5/2)**
1985	June 27	19.4～21.5	90	0.5(1/2)
1986	June 12	12.0～28.8	65	0.3(1/3)
1987	June 4	19.0～35.1	65	1.5(3/2)
1988	June 8	23.2～29.6	83	0.3(1/3)
1989	June 28	17.5～29.7	75	2.3(7/3)
1990	June 21	18.7～28.8	82	1.0(3/3)

* When mosquito appeared
** Number in parentheses means the total number of female mosquitoes/traps

The dates of peak population of *Cx. tritaeniorhynchus* and the meteorological data at that time are listed in Table 3. The highest population density of *Cx. tritaeniorhynchus* from 1984 to 1990 was observed during the period from mid-August to early September, but in late July in 1987. The air temperature was between 18.5 to 34.2°C and relative humidity from 71 to 89 per cent. The maximum number of *Cx. tritaeniorhynchus* in 1984 was 706.6 per trap-night. In 1985 the number decreased to 229.5 and 171.7 in 1986. In 1987 the number increased again to 205.3 and to 253.7 in 1988. In 1989 the number decreased to 120.7.

In Table 4, the dates when *Cx. tritaeniorhynchus* were not collected are listed according to the year studied. *Cx. tritaeniorhynchus* was not observed from the area in early and late October.

Table 3. Date of peak population of *Cx. tritaeniorhynchus* and meteorological data at that time

Year	Date of peak popul.	Temp. (°C)	Humidity (%)	Average No./trap-night
1984	Aug. 31	22.6～27.1	86	706.6(3,548/5)*
1985	Aug. 15	23.5～29.4	89	229.5 (659/3)
1986	Aug. 14	22.2～30.9	81	171.7 (515/3)
1987	July 23	20.6～28.6	88	205.3 (616/3)
1988	Sep. 1	18.7～30.7	72	253.7 (761/3)
1989	Sep. 6	18.5～27.6	75	120.7 (362/3)
1990	Aug. 22	24.5～34.2	71	205.7 (617/3)

* Number in parentheses means the total number of female mosquitoes per trap-nights

Table 4. Date of disappearance of *Cx. tritaeniorhynchus* and meteorological data

Year	Date of disappearance of mosquito	Temperature (°C)	Humidity (%)
1984	Oct. 6	8.0~22.9	67
1985	Oct. 24	9.3~23.0	68
1986	Oct. 2	11.5~17.4	83
1987	Oct. 8	13.2~28.5	70
1988	Oct. 26	8.4~23.1	70
1989	Oct. 11	10.6~25.1	81
1990	Sep. 26	15.8~24.8	65

Table 5. Seasonal prevalence of *Cx. tritaeniorhynchus* by the average numbers collected in each trap during seven years in Kyungsan county, Kyungpook Province

Year	Average number of female mosquitoes per trap-night				
	June	July	Aug.	Sep.	Oct.
1984	1.1	19.2	133.5	55.8	0.1
1985	0.1	23.6	156.0	92.2	3.1
1986	0.2	17.9	113.8	63.4	0.1
1987	1.3	111.9	107.3	16.6	0.2
1988	0.4	50.3	36.5	70.3	1.5
1989	0.6	13.7	24.3	45.6	1.5
1990	0.6	22.0	141.5	67.5	—

* No *Cx. tritaeniorhynchus* were collected in May and November every year.

The seasonal prevalence of *Cx. tritaeniorhynchus* collected by light traps are summarized in Table 5. In general, *Cx. tritaeniorhynchus* was collected in five months, from June to October every year. In 1984, the average number of female *Cx. tritaeniorhynchus* per trap-night in June was 1.1, it increased to 19.2 in July, and reached the maximum number 133.5 in August. In September, the average number decreased to 55.8, in October to 0.1, and none were collected in November. The general patterns of seasonal prevalence in other years were similar to those in 1984. It was found that the average number of *Cx. tritaeniorhynchus* rapidly decreased after 1985, and the number became particularly low in 1989. The highest population observed in August during the initial three years, but delayed in the following years, accompanied by decreases in the number of mosquitoes.

The relative abundance and MPI calculated for successive years after 1984 in correlation with the incidence of Japanese encephalitis are shown in Table 6 and illustrated in Fig. 2. A marked decrease in MPI was obtained in successive years.

The general patterns of engorgement rates, as calculated by dividing the number engorged with the total, in the other years were similar to those for 1984. The numbers of total and engorged female mosquitoes collected in a pigsty and on human baits in 1990 are shown in Table 7. *Cx. tritaeniorhynchus* attempted to feed from 19 : 00 onward, and the peak numbers of the mosquitoes showed two peaks, one between 20 : 00~21 : 00 and another between 04 : 00~05 : 00 on August 13~14 and August 30~31. In the trend of nocturnal activity of *Cx. tritaeniorhynchus*, on becoming dark they became very active, gradually decreasing in activity towards midnight, but slightly increasing towards dawn. The hourly distribution of *Cx. tritaeniorhynchus* is not apparent at the human baited trap, because of very small numbers collected.

The overall rate of engorgement at three observations on the pigs was from 7.1% in July 27~28 to 19.9% in August 30~31, with an average of 17.0%.

Table 6. Decrease of *Cx. tritaeniorhynchus* population in successive years after 1984 in correlation with the incidence of Japanese encephalitis

Year	Total No. collected	MPI*	JE	
			No. cases**	incidence (%)
1984	12,875	702.3	0	0
1985	3,101	130.1	0	0
1986	2,398	100.0	0	0
1987	3,184	199.5	3	0.007
1988	2,124	83.7	1	0.002
1989	877	30.8	0	0
1990	2,779	115.9	1	0.002

* Mean percent index
** Based on the reports from Cities and Provinces under Communicable Diseases Control Law

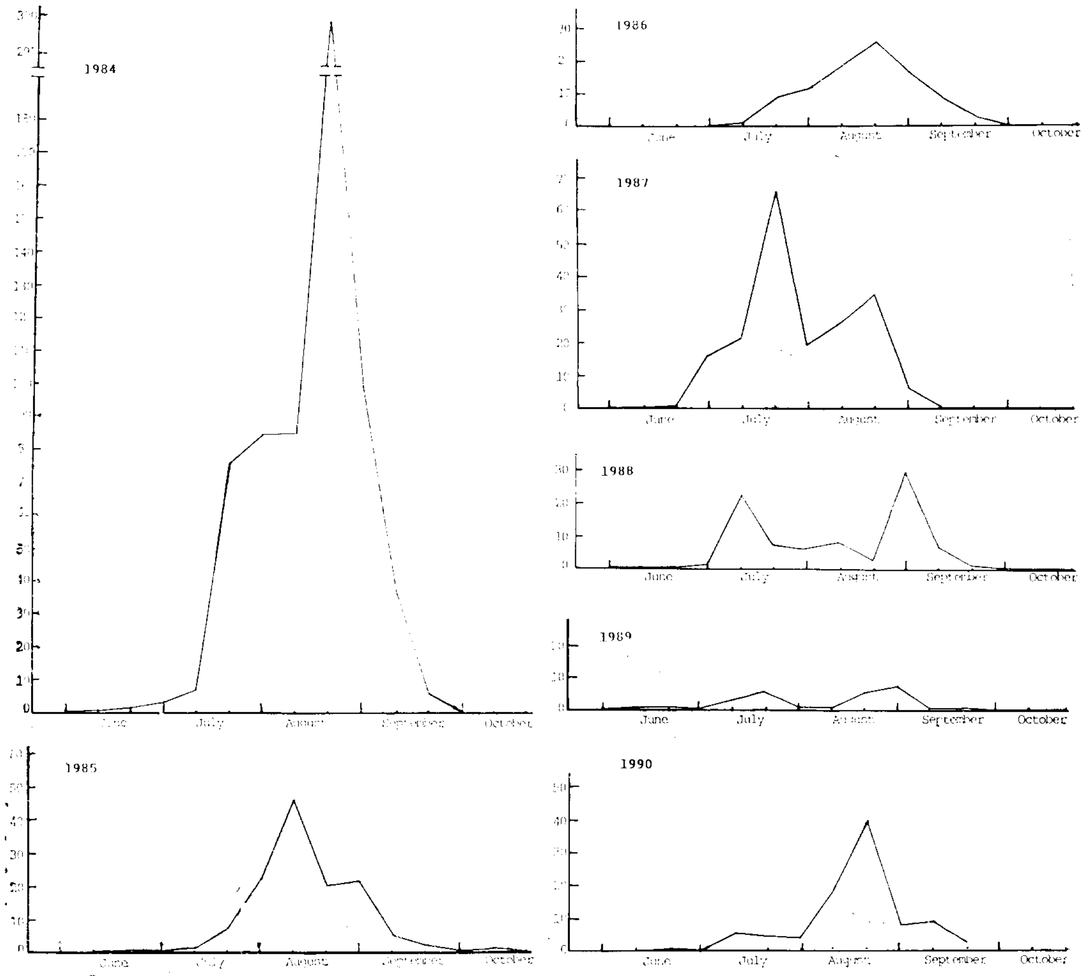

Fig. 2. Annual prevalence of *Culex tritaeniorhynchus* as shown in MPI calculated from the data oı mosquito collection at 3 stations.

Table 8 shows the number and percentages of engorged and unengorged female *Cx. tritaeniorhynchus* collected by light traps at three locations. The overall rates of engorgement which reflect the blood-sucking activity of *Cx. tritaeniorhynchus* in 1984 were in the order of 59.0% on the piggery, 37.6% on cow-stall, and 12.0% on human-dwelling. The general patterns of engorgement rates, as calculated by dividing the number engorged with the total, in the other years were similar to those for 1984.

The monthly fluctuation in the blood-sucking rate of *Cx. tritaeniorhynchus* is shown in Table 9. The rate was 22.3 to 44.4% in July and 41.2 to 52.8% in September. Although the rate decreased in October, it was kept on the level of 10.0%.

The age structures of immature stages of *Cx. tritaeniorhynchus* and population densities per m^2 are shown in Table 10. The densities of *Cx. tritaeniorhynchus* in rice fields was highest in mid-August, with an average number per m^2 of 14,900. After the last part of September, such densities showed a marked decrease and the larvae or pupae were rarely found until rice plants were harvested.

Table 11 shows organophosphate resistance levels of larval *Cx. tritaeniorhynchus* reared for one generation in the laboratory and compares with that of susceptible laboratory strain.

Table 7. The results of overnight *Cx. tritaeniorhynchus* collection by light trap in a pigsty and on human bait (1990)

Hours	July 27～28		August 13～14		August 30～31	
	Light trap	Man	Light trap	Man	Light trap	Man
19 : 00～20 : 00	3 (0)*	0	15 (1)	0	50 (7)	0
20 : 00～21 : 00	14 (3)	0	71 (6)	0	58(10)	1
21 : 00～22 : 00	4 (0)	0	14 (4)	1	26 (8)	3
22 : 00～23 : 00	3 (0)	1	8 (2)	1	13 (4)	1
23 : 00～24 : 00	0 (0)	0	16 (3)	0	21 (7)	1
24 : 00～01 : 00	5 (0)	0	5 (2)	0	10 (4)	0
01 : 00～02 : 00	1 (0)	0	15 (2)	1	15 (2)	1
02 : 00～03 : 00	2 (0)	0	15 (0)	1	12 (3)	1
03 : 00～04 : 00	7 (0)	1	10 (0)	0	17 (1)	0
04 : 00～05 : 00	3 (0)	0	21 (8)	0	34 (7)	0
05 : 00～06 : 00	0 (0)	0	15 (1)	0	10 (0)	0
Total	42 (3)	2	205(31)	4	266(53)	8
Temperature(°C)	29.3		30.1		26.9	
Humidity(%)	73		67		76	

* Number in parentheses means number of engorged female mosquitoes

Table 8. Comparison of total and engorged number of *Cx. tritaeniorhynchus* collected by light traps at three locations

Year	Location	No. collected	No. engorged
1984	A	1,377	813(59.0)*
	B	2,093	787(37.6)
	C	225	27(12.0)
	Subtotal	3,695	1,627(44.0)
1985	A	1,593	598(37.5)
	B	1,343	394(29.3)
	C	166	8 (4.8)
	Subtotal	3,102	1,000(32.2)
1986	A	1,095	547(50.0)
	B	1,176	485(41.2)
	C	127	9 (7.1)
	Subtotal	2,398	1,041(43.4)
1987	A	1,547	707(45.7)
	B	1,526	651(42.7)
	C	111	12(10.8)
	Subtotal	3,184	1,370(43.0)
1988	A	808	395(48.9)
	B	1,223	403(33.0)
	C	94	4 (0.4)
	Subtotal	2,125	802(37.7)
1989	A	382	156(40.8)
	B	473	192(40.6)
	C	22	0 (0.0)
	Subtotal	877	348(39.7)
1990	A	1,018	319(31.3)
	B	1,609	479(29.8)
	C	152	1 (0.7)
	Subtotal	2,779	799(28.8)
	Total	18,160	6,987(38.5)

* Number in parentheses means the percentage of engorged females.
Location A: Piggery, B: Cow-stall, C: House dwelling

The larval *Cx. tritaeniorhynchus* showed a high resistance against 5 organophosphorus compounds. Among the compounds, *Cx. tritaeniorhynchus* was found to have resistance ratios against temephos and fenitrothion in Lc_{50} value of 64.0 ppm and 10.8 ppm, respectively. The Lc 50 values to diazinon and malathion were about 2,500 and 5,000 times high as that of susceptible strain. Of the mosquitoes tested in 1990, the resistance levels and resistanc ratios to diazinon were increased, but in malathion and fenthion the ratios were slightly decreased. No fluctuation was found in resistance levels of fenitrothion and temephos.

Table 12 lists the effects of mating, association

Table 9. Monthly fluctuation of total and engorged number of *Culex tritaeniorhynchus* collected by light traps

Year	June		July		August		September		October	
	No. collected	No. engorged (%)	No. collected	No. engorged (%)	No. collected	No. engorged (%)	No. collected	No. engorged (%)	No. collected	No. engorged (%)
1988	9	1 (11.1)	604	268 (44.4)	438	102 (23.3)	1,055	435 (41.2)	18	2 (11.1)
1989	7	0 (0)	151	55 (36.4)	291	109 (37.5)	410	184 (44.9)	18	2 (11.1)
1990	7	0 (0)	264	59 (22.3)	1,698	383 (22.6)	810	362 (44.7)	—	—

Table 10. Age structures of immature stages of *Cx. tritaeniorhynchus* in the study area (1990)

Date	Total No. in the study area at the median age of each stage ($\times 10^3$)				
	L1	L2	L3	L4	Pupa
Jul. 13	14				
Jul. 19				2	
Jul. 27	64	37	53	18	18
Aug. 2	67	50	44	36	18
Aug. 10	10	375	284	157	24
Aug. 19		380	289	172	35
Aug. 23		15	25	17	3
Aug. 30	48	19		12	7
Sep. 6	46	14	11	12	6
Sep. 13	25	18	49	14	12
Sep. 20	22	11	19	11	11
Total	296	919	774	451	134

Table 11. Resistance levels and resistance ratios of larval *Cx. tritaeniorhynchus* exposed to 5 organophosphorus compounds for 24 hours

	1987			1990	
	Lc 50	R.R.*	S.S.**	Lc 50	R.R.
Diazinon	17.0	1,133	0.015	38.0	2,533
Malathion	20.8	5,200	0.0042	18.6	4,650
Fenitrothion	9.5	13,571	0.0007	10.8	15,429
Fenthion	3.3	2,357	0.0014	3.2	2,286
Temephos	61.8	79,231	0.0007	64.0	91,429

* Resistance ratio
** Data reported by Department of Medical Entomology, NIH, Japan

and/or egg deposit on lifespan of *Cx. tritaeniorhynchus* tested by comparing six groups. In the group of females associated with equal number of males, the average lifespan of females was longer than that of virgin females and males, whereas the average lifespan of mated males and/or those associated with females were shorter than those of virgin males.

The data presented in Table 13 list the biological and life table characteristics of Kyungsan strain *Cx. tritaeniorhynchus* and compare the present results with those of Nagasaki and Taipei strains described by Reisen *et al.* (1979). The life expectancy of *Cx. tritaeniorhynchus* in the present study was 28.33 days for males and 59.81 days for females. The net reproductive rate was found to be 7.81% living female offspring/female per generation, and generation

Table 12. Effects of mating, association and/or egg deposit on lifespan of *Cx. tritaeniorhynchus* (1990)

Group	Average day lived			
	Female		Male	
	1	2	1	2
Virgin	64.65±18.70	59.85±16.21	34.15±16.77	36.21±17.27
Females with equal number of males (On sugar)	52.22±13.02	52.03±14.20	24.89±13.30	30.07±11.18
Females with equal number of males (On blood meal)	58.86±12.46	59.81±16.73	28.33±11.09	26.36±15.34

Table 13. Biological and life table characteristics of Kyungsan strain of *Cx. tritaeniorhynchus* (1990)

Country	Korea	Japan	Taiwan
Locality	Kyung-san	Naga-saki	Taipei
Generation in Lab.	1	128	120
Siphonal index	8.41	7.40	7.61
Adult size			
Wing lenght(mm) ♂	2.70	3.11	2.71
♀	3.28	3.46	2.92
Fecundity			
No. raft/cage	14.0	71.3	258.0
No. eggs/raft	188.9	172.8	142.8
Fertility			
No. larvae/raft	143.0	121.0	130.5
Hatching(%)	75.7	70.2	91.4
Life table statistics			
e_1 ♂	28.33	14.14	15.08
e_2 ♀	59.81	21.10	19.22
Ro	7.81	21.37	84.97
To	15.50	18.02	13.62
G	25.60	28.31	24.01

e_1 : Mean life expectancy at emergence in days
Ro : Net reproductive rate: living females per female per generation
G : Generation time in days
To : Age of mean cohort reproduction

time was 25.6 days.

DISCUSSION

Since JE was first recognized as a distinct disease during a severe epidemic which occurred in the whole country of Japan except Hokkaido in 1924, Yamada (1933) suggested that mosquitoes might be involved, because the human JE cases followed the midsummer population peak of *Cx. tritaeniorhynchus*. After the establishment of experimental infection of JE by *Cx. tritaeniorhynchus* and isolation of JE virus from them in nature (Mitamura *et al.*, 1937 & 1938), biological, ecological, sero-epidemiological, and virological studies on JE and its vector mosquitoes have been conducted by many investigators in Japan, China, Korea, and eastern Asia.

In the studies on JE in Korea, little work was done before the end (1945) of the Japanese occupation, although a disease called "summer encephalitis" has been recognized and *Cx. tritaeniorhynchus* was thought to be the main vector. It was after the first report on the isolation of JE virus among U.S. army soldiers in Kunsan area (Sabin *et al.*, 1947), and after the occurrence of a large nationwide epidemic in 1949. That many investigators have made studies on the epidemiology of JE in Korea (Deuel *et al.*, 1950; Hullinghorst *et al.*, 1951; Chang *et al.*, 1959; Chun, 1975; Kono and Kim, 1969; Kim, 1975 & 1986), and on the seasonal prevalence of vector mosquitoes (Lee *et al.*, 1969; Shin *et al.*, 1971; Self *et al.*, 1973b; Ree *et al.*, 1973; Mathis and Jolivet, 1974; Pae *et al.*, 1976; Frommer *et al.*, 1977 & 1979; Lee *et al.*, 1984; Joo and Wada, 1985). As a result, it has become clear that JE is one of the most serious mosquito-borne diseases among the residents, especially children in Korea.

On the JE epidemic among the residents in Korea, Sabin *et al.* (1947) conducted a study in American soldiers stationed in Kunsan area, and observed four cases of JE during the summer of 1946. A virus recovered from a patient who dies was identified as that of JE. A specific diagnosis of the nonfatal cases was accomplished by means of complement fixation tests. These data conclusively established the presence of JE virus in Korea. At the same time, they carried out serologic surveys of native Koreans and of indigenous domestic animals in four different areas of southern Korea, and indicated that the virus of JE was widely disseminated in this country.

A study of Hullinghorst *et al.* (1951) reported that the Korean epidemic during the summer months of 1949 was caused by the virus of JE, and that serums of normal Koreans subjected to anamnestic evaluation and specimens from domestic animals indicated wide dissemination of the virus in Korea. Kono and Kim (1969) carried out an epidemiological study on the features of JE in Korea from 1949 to 1966, and made comparisons with the situation in China and Japan. They reported that a large fluctuation in the annual number of cases and deaths was one of the epidemiological characteristics of JE in Korea in comparison to the regular annual incidence in Japan, and also commented that Jeonpook Province was always the focus of the epidemics.

Similar results in epidemiological features of JE in Korea have been obtained by Chang *et al.* (1959), Kim (1975), and Kim (1986). As shown in Table 6, the incidence rate reported during the period from 1984 to 1990 is based on the reports from Cities and Provinces under Communicable Diseases Control Law. However, the reports from Cities and Provinces are not sufficient to determine the true incidence rate of all JE. Nevertheless, the results are quite comparable with earlier reports based on reported cases of JE in Korea during the period from 1949 to 1983 (Kim, 1986). The present results show a marked decrease in the incidence of JE compared with earlier reports available. The exact cause of the lower incidence of JE is not known, but there are several factors such as vaccination of children aged 3 to 15 years and decrease of the vector mosquito population.

Wada (1972) in a study of a theoretical model for JE epidemic demonstrated that the vector infections in the decreasing phases of vector populations was smaller than other times. In the survey of vector mosquitoes of JE in Korea, Lee *et al.* (1969) conducted a study of JE virus isolation from mosquitoes, and reported that 5 strains of JE virus were isolated from *Cx. tritaeniorhynchus*, one strain from *A. vexans nipponi*, and two strains from overwintering *Cx. pipiens pallens*, and commented that the principal vector of JE in Korea was *Cx. tritaeniorhynchus*. From their mosquito survey, it was found that *Cx. pipiens pallens* was the most prevalent species, and next in order was *An. sinensis*, with *Cx. tritaeniorhynchus* taking the 4th place.

Shin *et al.* (1971) in a study on seasonal prevalence of mosquitoes throughout the country, particular with reference to JE vector mosquitoes, reported that the population densities of *Cx. tritaeniorhynchus* were remarkably different between urban and rural areas, *i.e.*, high population densities in the vicinity of large and newly developing cities, and low densities in rural areas. Self *et al.* (1973) carried out an ecological study on *Cx. tritaeniorhynchus* as a vector of Japanese encephalitis, and reported that the dates and duration of the population peaks in semirural suburbs of Seoul and Pusan were markedly different from those at a rural rice-growing site, and also stressed that a short period of man-vector contact occurred at each study site at low densities when the natural population was at its peak.

In the recent studies, Joo and Wada (1985) conducted a survey of seasonal prevalence of the vector mosquitoes of JE virus in Kyungpook Province, Korea. It was found that among the 34,571 mosquitoes collected in animal shelters and human dwellings by light traps, approximately 45.0% were *Cx. tritaeniorhynchus*, 34.0% *Cx. pipiens pallens* and 19.0% *An. sinensis*. In the general patterns of seasonal prevalence, *Cx. tritaeniorhynchus* first appeared in mid-June, and were trapped in large numbers during the periods from mid-August to early September, showing a simple sharply pointed one peak curve, while *Cx. pipiens pallens* was found to be active through almost the entire season showing irregular curves with several peaks. The results presented in Table 5 indicate that the highest population of *Cx. tritaeniorhynchus* was clearly observed in August during the initial three years, and was found to be delayed in the following years, accompanied by the decrease in the number of mosquitoes.

Although the main reasons for the decrease in population levels of *Cx. tritaeniorhynchus* are not readily apparent, it was considered to be due to the extensive use of chemical insecticides in rice farming, changes in the rice culture system and/or rural environment such as water management of rice fields, high temperature, and small precipitation *etc.*, livestock and natural enemies, and reduction of rice fields by urbanization. Such consideration was also recognized by Wada *et al.* (1967), Kamimura and Katori (1969), Self *et al.* (1973a,b,c & 1974), Shim and Self(1973), Kamimura and Watanabe (1973), Buei and Ito (1974), Shimada (1974), Mogi (1978 & 1984), Maeda *et al.* (1978), Ree *et al.* (1979, 1980 & 1981), Kamimura and Maruyama (1983), and Kim (1986).

From the results presented in Table 5 and Table 14, the seasonal prevalence of *Cx. tritaeniorhynchus* has been shown usually in the number of mosquitoes collected by a light trap, but the numbers were found to fluctuate day by day. Therefore, the total or mean value seems to be unfit for comparison of the abundance of *Cx. tritaeniorhynchus.* On this point, Maeda *et al.* (1978) proposed to use the mean percent index (MPI), being calculated from the data of mosquito collections, for comparison of the annual abundance of mosquitoes. They also reported that *Cx. tritaeniorhynchus* had decreased after 1965 and this decrease was correlated with the reduction of human patients of JE in Japan. As Yasutomi and Takahashi (1987) indicated, the reduction of the vector population in 1970's seems to be due to the change of insecticides from BHC and/or DDT to organophosphorus compounds and/or carbamates, to the introduction of intermittent irrigation of rice fields or early planting of rice, and to the use of new herbicides that are effective in indirect control of mosquito larvae (Maeda *et al.*, 1978). In the present study, *Cx. tritaeniorhynchus* blood feeding success observed was sometimes a reflection of mosquito abundance. In practice, *Cx. tritaeniorhynchus* abundance during 1984 was greater than 1985, which was greater than 1987. The same relationship held true for the number of engorged mosquitoes collected during those years. However, daily engorgement success was not always linked to overall mosquito abundance. In this study, in 1988 *Cx. tritaeniorhynchus* was most abundant in September, but engorgement of females has the highest rate in July. The results of a monthly fluctuation of engorged *Cx. tritaeniorhynchus* of all three years indicated that blood feeding was significantly associated with the rainfall. Day and Curtis(1989) in a study of

Table 14. The reported average number per trap-night of *Cx. tritaeniorhynchus* by month in Korea

Source	Localities	May	June	July	August	September	October	Remarks
Lee *et al.* (1969)	Seoul	0	1.0	11.5	8.3	7.0	0	Results of 1965
Shin *et al.* (1971)	Seoul	0	0.1	15.4	108.6	60.3	0.1	
	Pusan	0	1.2	111.7	745.7	363.7	0.1	
	Suwon	0	0.1	2.1	17.0	2.2	0	
Self *et al.* (1973b)	Pusan	0.3	1.0	110.0	375.0	401.0	—	Results of 1971
	Sintain	0	3.0	258.0	25.0	2.0	—	
	Seoul	0	0	16.0	99.0	84.0	—	
Pae *et al.* (1976)	U.S. Army installations and Chinju	—	0.04	2.1	6.6	1.7	—	Results of 1974
	Yosu & Taesung-dong	—	0.01	0.4	2.9	2.4	0.3	Results of 1975
Frommer *et al.* (1977)	U.S. Army installations & Cheju city Yosu, Taesung-dong	0	0.01	0.9	3.6	1.7	—	Results of 1976
Fromer *et al.* (1979)	U.S. Army installations	0	0	1.1	10.7	5.3	—	Results of 1977
Lee *et al.* (1984)	U.S. Army compounds	0	4.4	253.1	665.5	144.6	4.9	Results of 1979~1980
Joo & Wada (1985)	Kyungpook Province	0	2.3	96.2	556.6	155.6	0.4	Results of 1984

influence of rainfall on *Cx. nigripalpus* blood-feeding behaviour in Indian River county, Florida, reported that *Cx. nigripalpus* abundance and blood feeding behaviour was tied closely with daily rainfall patterns. The relationship between adult abundance and rainfall has been reported for *Cx. nigripalpus* (Provost, 1973), *Cx. tritaeniorhynchus* and *Cx. gelidus* (Olson *et al.*, 1983) and *Cx. annulirostris* (Russel, 1986).

The results given in Table 7 indicate that the nocturnal activity of the female *Cx. tritaeniorhynchus* was not always similar by collection methods even on the same night. It has been known that environmental factors such as light, temperature, humidity, wind-borne stimuli, *etc.* are essential in determining the attraction of mosquitoes. Although these factors should be important in determining the attraction of mosquitoes, this data can not be explained fully only by the hourly changes of these factors because the meteorological conditions were considered nearly the same at least on the same night at the sites where the collection was made (Wada *et al.*, 1970 & 1975; Joo and Wada, 1985). In the present study the hourly prevalence of female *Cx. tritaeniorhynchus* had two peaks, one between 20:00∼21:00 and the other between 04:00∼05:00 on August 30-31. These results are similar to data reported by Wada *et al.* (1970), Kanda *et al.* (1975), Joo and Wada (1985), and Lee *et al.* (1986).

The immature stages of *Cx. tritaeniorhynchus* were first found in rice fields in mid-July. The highest average density was 14,900 per m^2 on mid-August. In mid-September, such densities showed a marked decrease and both larvae and pupae were rarely found until rice plants were harvested. In Korea, adult *Cx. tritaeniorhynchus* were always collected before the season's first larvae could be found. A study of Ree *et al.* (1976) reported that female *Cx. tritaeniorhynchus* hibernated only in the warmer, southern latitudes of Korea, and then moved progressively northwards by a series of dispersal flight until Seoul area was finally repopulated by mid-summer. From a study on the ecology of *Cx. tritaeniorhynchus*, Self *et al.* (1973b) reported that the use of agricultural insecticides had reduced larval rice field population throughout Korea.

The amount and spatial distribution of immature larvae of *Cx. tritaeniorhynchus* populations in rice field areas were examined by Mogi and Wada (1973), Wada and Mogi (1974), Somboon *et al.* (1989). Somboon *et al.* (1989) in studies on the JE vectors in northern Thailand reported that the average numbers of larvae plus pupae per m^2 rice fields was highest in July when the fields were ploughed, but in the period from transplanting to harvesting, the densities were very low. The results in present study are similar to those reported by Mogi and Wada (1973), Wada and Mogi (1974), Ree *et al.* (1976), and Somboon *et al.* (1989).

In the studies of insecticide resistance for bloodsucking insects and arthropods of medical importance, Hurlbut *et al.* (1952) made a survey of resistance of Korean body lice and reported for the first time that the body lice was DDT-resistant. Thereafter, organophosphorus compounds were introduced into Korea as a substitute for DDT and many organophosphate, carbamate and pyrethroid compounds have also been imported for medical and/or agricultural pests control. Shim *et al.* (1979) carried out studies on the resistance of insecticides against *Cx. tritaeniorhynchus* in Korea, and reported that organophosphorus compounds developed resistance for 8-folds more than in 1972 in Sintains train, and dusban showed highly susceptible value in Lc_{50} 0.00625 ppm despite frequent application for public health insecticides. Ree *et al.* (1980) in a field evaluation on the resistance of agricultural and/or public health pesticides against JE vector mosquitoes reported that the reduction rate of the larval *Cx. tritaeniorhynchus* in the natural rice fields after the application of pesticides by the farmer showed the same results of the experimental condition. They also indicated that the pesticide application in the rice fields by the farmer remarkably reduced the population densities of most species of aquatic organisms in the rice field besides mosquitoes. In recent years, from their studies on insecticide resistance of vector mosquitoes of JE in Korea, Baik and Joo (1987) reported that *Cx. tritaeniorhynchus* had developed high resistance to most of the insecticides as compared with the results of susceptible strain reported by Yasutomi and Takahashi (1987). Similar results in vector mosquitoes have been obtained by Hwang *et al.* (1965), Lee (1969), Shim and Self (1973), Self *et al.* (1974), Shim and Kim (1980 & 1981), Shim *et al.* (1982), Kamimura and Maruyama (1983).

In the present study, the larval *Cx. tritaeniorhynchus* showed high resistance to diazinon and malathion with Lc_{50} values of 38.0 ppm and 18.6 ppm, respectively. The more increased resistance to temephos and fenitrothin was discovered in *Cx. tritaeniorhynchus* collected in Kyungsan county. The results of this study indicate that the resistance ratio to organophosphorus compounds in Kyungsan colonies of *Cx. tritaeniorhynchus*, relative to susceptible colonies, were nearly 2,500～91,000 times.

The main breeding sites contributing to populations of *Cx. tritaeniorhynchus* in Korea were evidently rice fields. The Koreans have been striving for self-sufficiency in rice by increasing yields on existing paddy acreage and they have relied on chemical fertilizers, insecticides and fungicides. The intensive use of insecticides and fungicides for the control of agricultural and/or medical pests, which transmit communicable diseases during the summer season, by government officials and by residents have greatly influenced the populations and resistance of the insects and arthropods of medical importance. Such consideration was also recognizied by Self *et al.* (1973a), Maeda *et al.* (1978), and Mogi (1978). Higher insecticide resistance of *Cx. tritaeniorhynchus* in the present study suggests that it is probably related to some differences in the opportunity of contact to insecticides and fungicides.

Geographic variations among the life table characteristics for various species of mosquitoes have recently been studied in several parts of the world (Crovello and Hacker, 1972; Gomez *et al.*, 1977; Reisen *et al.*, 1979; Joo *et al.*, 1988). As a result, a considerable amount of field data and some laboratory data can be found related to the population dynamics, mating and biting rhythms, migratory habits, *etc.* of many species of mosquitoes. A study of Aslam *et al.* (1977) reported the influence of physiological age on the biting rhythm of *Cx. tritaeniorhynchus.* Also, Reisen *et al.* (1979) studied the geographical variation among the life table characteristics of *Cx. tritaeniorhynchus* from Asia.

In the present study the life expectancy at emergence of *Cx. tritaeniorhynchus* females was in general similar to the data of *Cx. pipiens quinquefasciatus* reported by Walter and Hacker (1974) and Gomez *et al.* (1977), and of *Ae. aegypti* reported by Crovello and Hacker (1972). While *Cx. tritaeniorhynchus* male life expectancy was generally longer than Nagasaki and Taiwan strains of *Cx. tritaeniorhynchus* reported by Reisen *et al.* (1979), it was similar to that of *Cx. pipiens quinquefasciatus* (Walter and Hacker, 1974) and *Ae. aegypti* (Crovello and Hacker, 1972).

LITERATURE CITED

Aslam, Y., Reisen, W.K. and Aslamkhan, M. (1977) The influence of physiological age on the biting rhythm of *Culex tritaeniorhynchus* Giles (Diptera: Culicidae). *Southeast Asian J. Trop. Med. Publ. Hlth.*, **8**:364-367.

Baik, D.H. and Joo, C.Y. (1987) Insecticide resistance of vector mosquitoes of Japanese encephalitis virus in Korea. *Keimyung Univ. Med. J.*, **6**:204-209.

Buei, K. and Ito, S. (1974) On the susceptibility of insecticides against the vector mosquito of Japanese encephalitis, *Culex tritaeniorhynchus* Dyar. *Jap. J. Sanit. Zool.*, **24**:219-233 (in Japanese).

Chang, K.S., Han, E.S. and Lee, P.H. (1959) Epidemiological observation of Japanese B encephalitis in Korea, 1958. *New Med. J.*, **2**:1,399-1,406 (in Korean).

Chun, C.H. (1985) Outline of acute infectious diseases in Korea. Choesin Eui Hak Sa. Co.

Crovello, T.J. and Hacker, C.S. (1972) Evolutionary strategies in life table characteristics among feral and urban strains of *Aedes aegypti* (L.). *Evolution*, **26**:185-196.

Day, J.F. and Curtis, G.A. (1989) Influence of rainfall on *Culex nigripalpus* (Diptera: Culicidae) blood-feeding behavor in Indian River county, Florida. *Ann. Entomol. Soc. Am.*, **82**:32-37.

Deuel, R.E. Hr, Bawell, M.B., Matumoto, M. and Sabin, A.B. (1950) Status and significance of inapparent infection with virus of Japanese B encephalitis in Korea and Okinawa in 1946. *Am. J. Hyg.*, **51**:13-20.

Frommer, R.L., Pae, C.M., Chong, C.S. and Lee, T.K. (1977) The distribution and abundance of mosquitoes collected from light traps in the Republic of Korea during 1976. *J. Korean Med. Ass.*, **20**:715-719.

Frommer, R.L., Pae, C.M. and Lee, T.K. (1979) The distribution and abundance of adult mosquitoes collected from light traps in the Republic of Korea during 1977. *J. Korean Med. Ass.*, **22**:373-381.

Gomez, C., Rabinovich, J.E. and Machade-Allison, C.E. (1977) Population analysis of *Culex pipiens fatigans* Wied. (Diptera: Culicidae) under laboratory conditions. *J. Med. Entomol.*, **13**:453-463.

Hullinghorst, R.L., Choi, Y.T. and Whatley, L.R. (1951) Japanese B encephalitis in Korea the epidemic of 1949. *J.A.M.A.*, **145**:460-466.

Hurlbut, H.S., Altman, R.M. and Nibley, C. (1952) DDT resistance in Korean body lice. *Sciences*, **115**:11-12.

Hwang, C.H., Paik, K.H., Kim, C.M. and Hong, H.K. (1965) A study of insecticides susceptibility test of *Culex* mosquitoes and a note biting activity of *Culex tritaeniorhynchus* Giles in Korea. *Korean J. Cent. Med.*, **9**:231-236.

Joo, C.Y., Baik, D.H. and Kim, J.B. (1988) Effects of mating or association of the sexes on longevity in *Culex pipiens quinquefasciatus* Say. *Keimyung Univ. Med. J.*, **7**:81-90.

Joo, C.Y. and Wada, Y. (1985) Seasonal prevalence of the vector mosquitoes of Japanese encephalitis virus in Kyungpook Province, Korea. *Korean J. Parasit.*, **23**:139-150.

Kamimura, K. and Katori, K. (1969) Seasonal occurrence of *Culex tritaeniorhynchus summorosus* in Toyama Prefecture, with special reference to the effect of aerial application of carbaryl dust on rice fields and Japanese encephalitis. *Jap. J. Sanit. Zool.*, **20**:87-94 (in Japanese).

Kamimura, K. and Maruyama, Y. (1983) Appearance of highly resistant strain of *Culex tritaeniorhynchus* to organophosphorus insecticides. *Jap. J. Sanit. Zool.*, **34**:33-37 (in Japanese).

Kamimura, K. and Watanabe, M. (1973) Some aspects of great diminution of *Culex tritaeniorhynchus summorosus*, the principal vector of Japanese encephalitis with special reference to the recent advance in agricultural methods. *Bochu-Kagaku*, **38**:245-253 (in Japanese).

Kanda, T., Joo, C.Y. and Choi, D.W. (1975) Epidemiological studies on malayan filariasis in an inland in Kyungpook, Korea. 2. The periodicity of the microfilaria and the bionomics on the vector. *Mosquito News*, **35**:513-517.

Kim, K.H. (1975) Recent epidemiological features of Japanese encephalitis in the Republic of Korea. *Int. J. Zoon.*, **2**:35-44.

Kim, K.H. (1986) Epidemiological features of Japanese encephalitis in the Republic of Korea. *In* K. Fukai (ed.), Virus vaccines in Asian countries, Univ. of Tokyo press, 125-133.

Kono, R. and Kim, K.H. (1969) Comparative epidemiological features of Japanese encephalitis in the Republic of Korea, China (Taiwan) and Japan. *Bull WHO*, **40**:263-277.

Lee, H.I., Choi, D.W., Baik, D.H. and Joo, C.Y. (1986) Epidemiological studies on malayan filariasis in an inland area in Kyungpook, Korea. 3. Ecological survey of vector mosquitoes of *Brugia malayi*. *Korean J. Parasit.*, **24**:15-24.

Lee, H.W., Min, B.W. and Lee, Y.W. (1969) Japanese encephalitis virus isolation from mosquitoes of Korea. *J. Korean Med. Ass.*, **12**:429-440.

Lee, K.W. (1969) Insecticide test for resistance on adults of *Anopheles sinensis* and *Culex tritaeniorhynchus* in Korea. *Korean J. Parasit.*, **7**:29-31 (in Korean).

Lee, K. W., Gupta, R.K. and Wildie, J.A. (1984) Collection of adult and larval mosquitoes in U.S. Army Compounds in the Republic of Korea during 1979-1983. *Korean J. Parasit.*, **22**:102-108.

Maeda, O., Takenokuma, K. and Matsuyama, Y. (1978) Epidemiology studies on Japanese encephalitis in Kyoto city area, Japan, I. Evidence for decrease of vector mosquitoes. *Jap. J. Med. Sci. Biol.*, **31**:27-37.

Mathis, H.L. and Jolivet, P.H.A. (1974) Seasonal and yearby population variations of adult *Culex tritaeniorhynchus* in Korea. *WHO. VBC/74.* **499**: 1-7.

Mitamura, T., Yamada, S., Hazato, H., Mori, K., Hosoi, T., Kitaoka, M., Watanabe, S., Okubo, K. and Tenzin, S. (1937) On the mode of transmission of epidemic encephalitis: Experimental studies on its transmission by mosquitoes. *Trans. Soc. Pathol. Japan.* **27**:573-580.

Mitamura, T., Kitaoka, M., Kobayashi, E. and Okubo, E. (1938) Isolation of virus of Japanese epidemic encephalitis from mosquitoes caught in nature. *Tokyo Iji Shinshi*, **62**:820-824 (in Japanese).

Mogi, M. (1978) Population studies on mosquitoes in the rice field area of Nagasaki, Japan, especially on *Culex tritaeniorhynchus. Trop. Med.* (Nagasaki), **20**:173-263.

Mogi, M. (1984) Mosquito problems and their solution in relation to paddy rice production. *Prot. Ecol.*, **7**:219-240.

Mogi, M. and Wada, Y. (1973) Spatial distribution of larvae of the mosquito *Culex tritaeniorhynchus summorosus* in a rice field area. *Trop. Med.* (Nagasaki), **15**:69-83.

Morinaka and Ohnaka (1926) Uber die Encephalitis lethargica. *Mansen no Ikai*, No. 67. (Quoted by Kaneko and Aoki, 1928-Ueber die Encephalitis epidemica in Japan. *d. inn. Med. u. Kinderh.*, **34**: 342-456.

Olson, J.G., Atmosoedjono, S., Lee, V.H. and Ksiazek, T.G. (1983) Correlation between population indices of *Culex tritaeniorhynchus* and *Cx. gelidus* (Diptera: Culicidae) and rainfall in Kapuk, Indonesia. *J. Med. Entomol.*, **20**:108-109.

Pae, C.M., Frommer, R.L., Chong, C.S., Endris, R.G. and Lee, T.K. (1976) The distribution and abundance of mosquitoes collected from light traps in the Republic of Korea during 1974 and 1975. *J. Korean Med. Ass.*, **19**:188-403.

Provost, M.W. (1973) Mosquito flight and night relative humidity in Florida. *Fla. Sci.*, **36**:217-225.

Ree, H.I. Hong, H.K., Shim, J.C., Lee, J.S., and Cho, H.W. (1979) Studies on the control effects of agricultural pesticide of the rice paddy breeding species in Korea(2). *Rep. NIH Korea*, **16**:311-316 (in Korean).

Ree, H.I., Hong, H.K., Shim, J.C., Lee, J.S., Cho, H.W. and Kim, C.L. (1980) Field evaluation on the resistance of agricultural and public health pesticide against Japanese encephalitis vector mosquitoes. *Rep. NIH Korea*, **17**:231-329.

Ree, H.I., Self, L.S., Hong, H.K., and Lee, K.W. (1973) Mosquito light trap survey in Korea 1969-1971. *Southeast Asian J. Trop. Med. Pub. Hlth.*, **4**:382-386.

Ree, H.I., Shim, J.C., Hong, H.K., Lee, J.S., Cho, H.W. and Kim, C.L. (1981) Studies on control effects of pesticide application against the vector mosquito larvae in rice field in Korea. *Korean J. Entomol*, **11**:39-45.

Ree, H.I., Wada, Y., Jolivet, P.H.A., Hong, H.K., Self, L.S. and Lee, K.W. (1976) Studies on overwintering of *Culex tritaeniorhynchus* Giles in the Republic of Korea. *ORSTOM. ser. Ent. Med. et Parasitol*, **14**:105-109.

Reisen, W.K., Siddiqui, T.F., Aslam, Y. and Malik, G.M. (1979) Geographic variation among the life table characteristics of *Culex tritaeniorhynchus* from Asia. *Ann. Entomol. Soc. Am.*, **72**:700-709.

Russell, R.C. (1986) Seasonal activity and abundance of the arbovirus vector *Culex annulirostris* Skuse near Echuca, Victoria, in the Murray Valley of southeastern Australia 1979-1985. *Aust. J. Exp. Biol. Med. Sci.*, **64**:97-103.

Sabin, A.B., Schlesinger, R.W., Ginder, D.R. and Matumoto, M. (1947) Japanese B encephalitis in American soldiers in Korea. *Am. J. Hyg.*, **46**: 356-375.

Self, L.S., Ree, H.I., Lofgren, C.S., Shim, J.C., Chow, C.Y., Shin, H.K. and Kim, K.H. (1973a) Aerial applications of ultra-low-volume insecticides to control the vector of Japanese encephalitis in Korea. *Bull. WHO.*, **29**:353-357.

Self, L.S., Shim, J.C. and Jolivet, P. (1974) Susceptibility of *Culex tritaeniorhynchus* and six other mosquitoes to insecticides in Korea. *ORSTOM ser. Ent. Med. et Parasitol.*, **12**:81-92.

Self, L.S., Shin, H.K., Kim, K.H., Lee, K.W., Chow, C.Y. and Hong, H.K. (1973b) Ecological studies on *Culex tritaeniorhynchus* as a vector of Japanese encephalitis. *Bull. WHO*, **49**:41-47.

Self, L.S., Tonn, R.J., Bai, D.H. and Shin, H.K. (1973c) Toxicity of agricultural pesticide applications to several mosquito species in south Korean rice field. *Trop. Med.*(Nagasaki), **15**:177-188.

Shiba, Y. and Chun, C.H. (1936) On epidemic encephalitis or socalled summer encephalitis occurring in Seoul last summer. ***Mansen no Ikai*, 180**: 1 (in Japanese).

Shim, J.C. and Kim, C.L. (1980) Studies on the susceptibility of public health insecticides against mosquitoes in Korea. *Rep. NIH Korea*, **17**:357-362.

Shim, J.C., and Kim, C.L. (1981) On the susceptibility of insecticides against vector mosquitoes. *Rep. NIH Korea*, **18**:249-255.

Shim, J.C., Ree, H.I. and Kim, C.L. (1982) Study on the susceptibility of insecticides against *Culex tritaeniorhynchus* larvae. *Korean J. Entomol.*, **12**: 41-45 (in Korean).

Shim, J.C. and Self, L.S. (1973) Toxicity of agricultural chemicals to larvivorous fish in Korean rice fields. *Trop. Med.* (Nagasaki), **15**:123-130.

Shimada, S. (1974) Epidemiology of Japanese encephalitis in Wakayama Prefecture, Examination on the effect of population density of *Culex tritaeniorhynchus. Ann. Rep. Wakayama Pref. Publ. Hlth. Lab.*, **20**:63-70 (in Japanese).

Shin, H.K., Hong, H.K., Lee, K.W., Yoon, H.S., Yoon, Y.H. and Ree, H.I. (1971) Studies on seasonal prevalence of mosquitoes throughout the country, with particular reference to Japanese encephalitis vector mosquitoes. *Rep. NIH Korea*, **8**: 109-115 (in Korean).

Somboon, P., Choochote, W., Khamboonruang, C., Keha, P., Suwanphanit, P., Sukontasan, K. and Chaivong, P. (1989) Studies on the Japanese encephalitis vectors in Amphoe Muang, Chiang Mai, Northern Thailand. *Southeast Asian J. Trop. Med. Pub. Hlth.*, **20**:9-17.

Sturtees, G. (1970) Effects of irrigation on mosquito populations and mosquito-borne diseases in man, with particular reference to rice field extension. *Int. J. Envihon. Stud.*, **1**:35-42.

Takai, T. (1933) *Jodai Shonika Zasshi*, **1**:21 (in Japanese).

Wada, Y. (1972) Theoretical model for Japanese encephalitis epidemic. *Trop. Med.* (Nagasaki), **14**: 41-54 (in Japanese).

Wada, Y., Kawai, S., Ito, S., Oda, T., Nishigaki, J. and Omori, N. (1967) Ecology of vector mosquitoes of Japanese encephalitis, especially of *Culex tritaeniorhynchus*. 1. Results obtained in 1965. *Trop. Med.* (Nagasaki), **9**:45-57.

Wada, Y., Kawai, S., Ito, S., Oda, T., Nishigaki, J. Suenage, O. and Omori, N. (1970) Ecology of vector mosquitoes of Japanese encephalitis, especially of *Culex tritaeniorhynchus*. 2. Nocuturnal activity and host preference based on all-night catches by different methods in 1965 near Nagasaki city. *Trop. Med.*(Nagasaki), **12**:79-89.

Wada, Y. and Mogi, M. (1974) Effeciency of the dipper in collecting immature stages of *Culex tritaenorhynchus summorosus*. *Trop. Med.* (Nagasaki), **16**:35-40.

Wada, Y., Mogi, M. and Nishigaki, J. (1971) Studies on the population estimation for insects of medical importance: III. Sequentical sampling technique for *Culex tritaeniorhynchus summorosus* larvae in the paddy field. *Trop. Med.* (Nagasaki), **13**:16-25.

Walter, N.M. and Hacker, C.S. (1974) Variation in life table characteristics among three geographic strains of *Culex pipiens quinquefasciatus. J. Med. Entomol.*, **11**:541-550.

Yamada, S. (1933) Consideration on the relation between epidemic encephalitis and mosquitoes. *J. Tokyo Soc. Med.*, **48**:176-183 (in Japanese).

Yasutomi, K. and Takahashi, M. (1987) Insecticidal resistance of *Culex tritaeniorhynchus* (Diptera: Culicidae) in Japan II. A country-wide survey of resistance to insecticides. *J. Med. Entomol.*, **24**: 604-608.

Yoshihara, H. (1932) *Chosen Igakkai Zasshi*, **22**: 1,036 (in Japanese).

=國文抄錄=

韓國에 있어서 日本腦炎의 疫學的, 媒介動物學的 調査

啓明大學校 醫科大學 寄生蟲學敎室
白 斗 鉉·朱 鍾 潤

慶北地域에서의 腦炎媒介모기, 작은빨간집모기(*Culex tritaeniorhynchus*)의 季節的 出現 消長과 群集變動이 日本腦炎 發生과 流行에 미치는 影響을 糾明하기 위해서 1984年부터 1990年까지 慶山郡 1個所에 誘蚊燈으로 1週日에 한번씩 成蟲을, 1990年 4月부터 9月까지 慶北農村振興院 附屬農場에서 모기幼蟲을 採集하였다.

1984年부터 1990年까지 誘蚊燈에 처음으로 작은빨간집모기가 採集되는 날짜는 年度別로 큰 差異를 나타내었으며, 6月 4日부터 28日 사이에 採集되었고, 가장 높은 群集密度를 보인 것은 8月 中旬에서 9月初였고, 그 後 점점 減少하여 10月 末에는 採集되지 않았다. 작은빨간집모기의 採集되는 數는 1985年 以後 급격히 減少하여, 1989年에는 가장 적은 數가 採集되었다. 첫 3年 동안은 最高 群集密度가 8月에 觀察되었고, 그 以後해에서 모기數의 減少와 함께 늦어지는 것을 알았다. 夜間活動性은 저녁 8～9時 사이에 가장 왕성하며, 그 後 점차減少하다가 새벽 4～5時 다시 약간 增加하였다. 작은빨간집모기 幼蟲은 7월 中旬에 논에서 처음으로 發見되었고, 그 密度는 8月 中旬에 가장 높았으며, 最高 群集密度는 $1m^2$當 平均數는 14,900마리였다. 9月 下旬 以後부터는 그 密度가 현저히 減少하였다. 작은빨간집모기 幼蟲은 5種의 有機燐劑에 對하여 높은 抵抗性을 나타내었다. 昆蟲 飼育室內에서 작은빨간집모기, 慶山 種의 生命表 特性에서 平均壽命은 암컷은 59.8日이었고, 수컷은 28.3日이었으며, Net reproductive rate는 7.8, Generation time은 15.5日였다.

[기생충학잡지, 29(1):67-85, 1991년 3월]