Appl. Entomol. Zool. **31** (1): 75–80 (1996)

Effect of Rice Plant Covering on the Density of Mosquito Larvae and Other Insects in Rice Fields

Masahiro TAKAGI, Akira SUGIYAMA[1] and Katsumi MARUYAMA[2]

Department of Medical Entomology, Institute of Tropical Medicine, Nagasaki University, Nagasaki 852, Japan
[1] *Department of Public Health, Faculty of Domestic Science, Nagoya Women's University, Nagoya 467, Japan*
[2] *Department of Epidemiology and Information, Mie Prefectural Institute of Public Health, Tsu 514, Japan*

(Received 9 June 1995; Accepted 31 October 1995)

The larval densities of *Culex tritaeniorhynchus*, *Anopheles sinensis* and other insects were compared in fields with and without rice plants, and in fields with short and tall rice plants. The density of *C. tritaeniorhynchus* was higher in unplanted and short rice planted sections of the rice fields. In the case of *A. sinensis*, a higher larval density was observed only in unplanted sections. Among the 7 families comprising 11 to 13 species of other insects, 5 species were more abundant in unplanted sections. The difference in larval densities among sections in rice fields was possibly due to oviposition preferences of females.
Key words: mosquito larval density, other insects, growing rice

INTRODUCTION

Mosquito larval densities in rice fields change with time and space. The relationship between mosquito larval density and height of rice plants has been repeatedly investigated because differences in rice plant heights due to growth or variety might affect the larval density of a mosquito species through changes in the microhabitat such as light conditions, temperature, mechanical obstruction, and nutritional state of the water. Succession of mosquito fauna was observed in association with the rice-growing cycle in irrigated rice fields of Kenya and The Gambia. Larvae of *Anopheles gambiae* s.l. GILES, the most important vector of malaria in African countries, were abundant during the early stage of the rice-growing cycle, but the larvae of this species became reduced in number as nursery rice gave way to a denser, higher, and more established rice (SNOW, 1983; SURTEES et al., 1970; CHANDLER and HIGHTON, 1975). The critical height of the rice plant affecting the drop in population density of *A. gambiae* s.l. was ca. 100 cm (CHANDLER and HIGHTON, 1976). A similar inverse relationship between mosquito density and height of rice plant was encountered in rice fields of India for *A. culicifacies* GILES (RUSSELL and RAO, 1940; SEN, 1948), and for both *A. culicifacies* and *A. subpictus* GRASSI (PRASAD et al., 1990). A tendency for density and height of rice plants to limit the populations of *A. quadrimaculatus* SAY was also reported for Louisiana rice fields where the number of *A. quadrimaculatus* larvae decreased as the plant density increased (CHAMBERS et al., 1979). In contrast, a positive correlation between mosquito density and rice-plant height was found for *Anopheles* spp. in both wild rice (*Zizania palustris*) and white rice (*Oryza sativa*) fields in California during the early rice growing stage (GARCIA et al., 1992).

In the case of culicine mosquitoes, *Culex vishnui* THEOBALD, an important vector of Japanese encephalitis, was determined to be the earliest breeder in rice fields in India (REUBEN, 1971). In Japan and India, a high larval density was observed shortly after the rice transplanting period for *C. tritaeniorhynchus* GILES, another important vector of the encephalitis (MAKIYA, 1967; REUBEN, 1971; MOGI, 1978; TAKAGI et al., 1995).

All of the comparative studies above were made in separate rice fields with either short plants or tall plants, or at different periods of rice cultivation. However, these comparisons are not appropriate for evaluating the effect of the presence or height of rice plants on mosquito occurrence, because conditions such as water quality in separate rice fields and at different periods are unlikely to be the same.

The aim of the present study was to evaluate the relationship between larval density of both *C. tritaeniorhynchus* and *A. sinensis* WIEDEMANN and the presence and height of rice plants more precisely. Two series of observations were performed in rice fields divided into two sections, each having special conditions. In the first series, mosquito larval density was examined in a rice growing area in which the field was divided into rice planted and unplanted sections. In the second series, observations were made in rice fields divided into short and tall rice sections. Mosquito larval density findings of the two series of observations are reported along with the densities of other noticeable insects.

MATERIALS AND METHODS

The studies were conducted in two rice growing areas, coded AN and MD, both of which were located in a plain area of Tsu, Mie Prefecture, central Japan. Each rice field was 30×100 m (rectangle). In AN, we prepared rice fields where rice was transplanted in only half of a rice field (30×50 m, planted section), and the other half of the rice field was left as an open water surface (unplanted section).

Larval densities (no./10 dips) of both *C. tritaeniorhynchus* and *A. sinensis* immatures, and other insects were monitored weekly for 6 weeks in 6 of these half-planted rice fields by dipping from early July to mid-August in 1984 (from just after the midseason drying to just before the final draining). The dipper used was 13 cm in diameter and 7.5 cm in depth. One sample was collected from each section, and each sample consisted of 10 dips made at 10 points, each more than 10 paces apart.

The other rice fields used (MD) were located in the experimental yard of the Faculty of Agriculture, Mie University, ca. 3 km from AN. In MD, tall and short varieties, both of which were transplanted in the same week (May 5–7, 1983), were planted in half of each rice field. From July 5, one sample was collected from each section of 5 or 6 rice fields weekly for 6 weeks by the same dipping method as described in AN.

All samples were brought back to the laboratory, and identified to species using a microscope.

Taking into account both the large daily fluctuation in numbers and the small sample size, statistical analysis by the TUKEY and KRAMER method (minimum significant differences) in SOKAL and ROHLF (1981) was performed for the overall study period after density data (numbers from 10 dips) were transformed by $\log(x+1)$.

On July 5th, the average plant height measured at 18 points of the 6 rice fields used (3 points each) was 68.1 ± 7.6 cm at the rice planted sections in AN. That on August 10th was 94.0 ± 10.3 cm. Average plant heights in MD were 45.0 ± 11.2 cm (2 points $\times$ 6 rice fields) for the short rice sections and 98.5 ± 12.9 cm (2 points $\times$ 6 rice fields) for the tall rice sections on August 8th. Light intensities on that day at 1 cm above the water surface ranged from 3,750–5,200 lx (2 points $\times$ 6 rice fields) at the former and 350–750 lx (2 points $\times$ 6 rice fields) at the latter, while that at the open water surface was $> 15,000$ lx in MD.

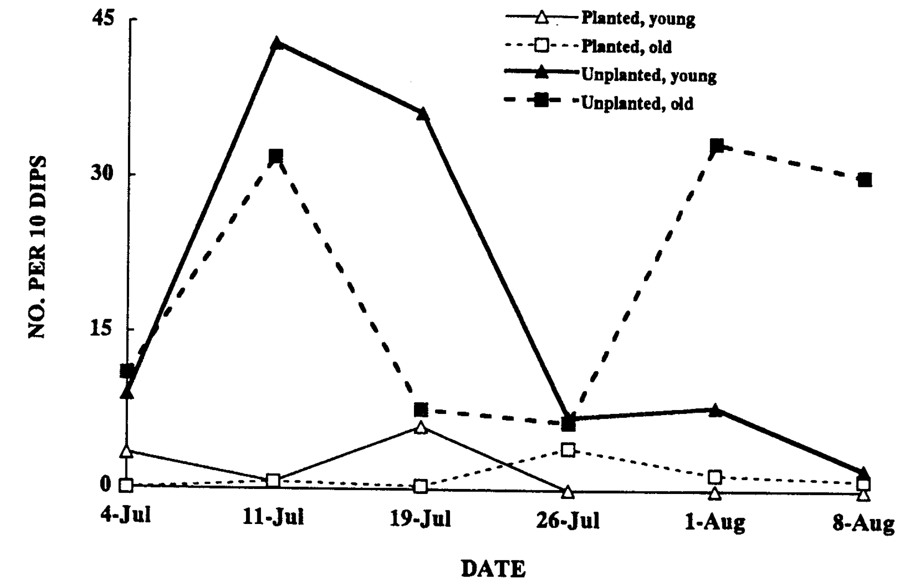

Fig. 1. Larval density (number of larvae per 10 dips) of *C. tritaeniorhynchus* at unplanted and planted sections of study rice fields in AN.

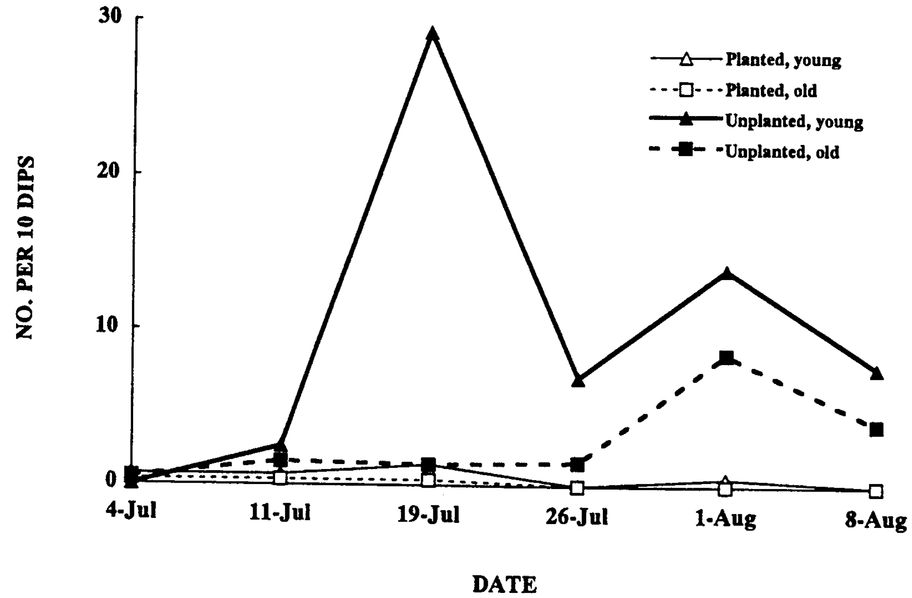

Fig. 2. Larval density (number of larvae per 10 dips) of *A. sinensis* at unplanted and planted sections of study rice fields in AN.

No insecticides were applied in either of the rice fields during the course of the study.

RESULTS

Comparison of mosquito density between planted and unplanted sections

The mosquito immatures collected from the rice fields in AN consisted of only *C. tritaeniorhynchus* and *A. sinensis* throughout the experimental period. The larval densities of both *C. tritaeniorhynchus* and *A. sinensis* at the unplanted sections were almost always higher

Table 1. Average density of *C. tritaeniorhynchus* and *A. sinensis* larvae at unplanted and planted sections of study rice fields in AN

Section	No. samples	Density of *C. tritaeniorhynchus* (SD)			Density of *A. sinensis* (SD)		
		1st & 2nd instars	3rd & 4th instars	Total larvae	1st & 2nd instars	3rd & 4th instars	Total larvae
Unplanted	36	17.8 (31.00)	23.1 (23.72)	40.9 (44.16)	11.4 (15.10)	3.1 (3.42)	14.5 (16.28)
Planted	36	2.1 (3.48)	0.8 (1.29)	3.0 (3.55)	0.6 (0.89)	0.2 (0.40)	0.9 (1.01)

Table 2. Average density of *C. tritaeniorhynchus* and *A. sinensis* larvae at short and tall rice sections in MD

Section	No. samples	Density of *C. tritaeniorhynchus* (SD)			Density of *A. sinensis* (SD)		
		1st & 2nd instars	3rd & 4th instars	Total larvae	1st & 2nd instars	3rd & 4th instars	Total larvae
Short rice	32	0.63 (0.130)	3.50 (0.634)	4.13 (0.679)	0.00 (0.061)	0.06 (0.062)	0.06 (0.084)
Tall rice	32	0.09 (0.092)	0.53 (0.448)	0.63 (0.480)	0.09 (0.043)	0.06 (0.044)	0.16 (0.059)

than those at the planted sections (Figs. 1 and 2). The overall average densities of both species at the two sections are shown in Table 1.

Overall average densities of young larvae (lst and 2nd instars) of *C. tritaeniorhynchus* at unplanted and planted sections were 17.8 and 2.1 individuals, respectively. The densities between the two sections were significantly different ($p < 0.02$). The averages of later stadium larvae (3rd and 4th instars) at the two sections were 23.1 and 0.8 individuals, respectively, a highly significant difference ($p < 0.0002$). For total larvae, the difference between sections was also statistically significant ($p < 0.001$). Higher larval density was confirmed in the unplanted sections irrespective of the age of *C. tritaeniorhynchus*.

The average density for *A. sinensis* was higher in unplanted sections irrespective of larval stage. Differences between the sections were always statistically significant ($p < 0.005$).

Comparison of density of mosquitoes between tall and short rice sections

Mosquito species collected from rice fields in MD were similar to those in AN. The densities of both *C. tritaeniorhynchus* and *A. sinensis* larvae in MD were too low to examine temporal changes. The overall average densities of *C. tritaeniorhynchus* in the short rice sections were 0.63, 3.50 and 4.13 for young larvae, old larvae and total larvae, respectively, while those in the tall rice sections were 0.09, 0.53 and 0.63 (Table 2). However, the differences in density between the two sections were statistically significant in this species ($p < 0.001$). By contrast, no significant difference was found between the two sections for *A. sinensis* ($p < 0.05$) (Table 2). The total numbers of *A. sinensis* larvae collected during the study period were only 2 at short rice sections and 5 at tall sections.

Comparison of densities of insects other than mosquitoes

A total of 7 families of Insecta representing ca. 11 to 13 species including at least 4 predators of mosquito larvae, were collected by dipping during the study. These were Agrionidae and Libellulidae of Odonata, Corixidae, Nepidae, Veliidae and Gerridae of Hemiptera and Dytiscidae of Coleoptera. All families were collected from unplanted sections. From planted sections, however, 3 families (Libellulidae, Gerridae and Nepidae) were not collected. In the case of Nepidae, only one *Laccotrephes japonensis* nymph was collected in

Table 3. Average density of macro invertebrates associated with mosquito larvae at unplanted and planted sections of study rice fields in AN

Section	No. samples	Density (SD)								
		Agrionidae	Libellulidae	Corixidae	Veliidae	Gerridae	*Guignotus* spp. larvae	*Guignotus* spp. adult	Dytiscidae larvae	Dytiscidae adult
Unplanted	30	1.47 (2.526)	0.87 (0.957)	1.43 (2.144)	5.90 (6.656)	5.47 (14.227)	4.27 (5.674)	7.73 (9.234)	0.47 (0.806)	0.67 (1.135)
Planted	30	0.60 (0.800)	0.00 (0.000)	0.23 (0.568)	13.43 (11.649)	0.00 (0.000)	0.53 (0.884)	7.47 (4.334)	1.00 (1.265)	0.27 (0.442)

Table 4. Average density of macro invertebrates associated with mosquito larvae at short and tall rice sections in MD

Section	No. samples	Density (SD)				
		Agrionidae	Libelllulidae	Corixidae	Veliidae	*Guignotus* spp.
Short rice	32	0.06 (0.078)	0.06 (0.141)	0.06 (0.051)	0.75 (0.331)	0.06 (0.062)
Tall rice	32	0.13 (0.055)	0.41 (0.100)	0.03 (0.036)	0.59 (0.234)	0.06 (0.044)

an unplanted section. As shown in Table 3, more nymphs of Odonata, predominantly *Ceriagrion* spp. (Agrionidae) and *Sympetrum* spp. (Libellulidae), were found in unplanted sections than in planted ones ($p < 0.05$). Densities of Corixidae, mainly composed of nymph and adult *Sigara substriata*, and Gerridae, composed of both stages of *Aquarius* spp. were also higher in the open water surface of unplanted sections than in the water surface canopied by grown rice plants ($p < 0.05$). On the other hand, the density of nymph and adult Vellidae, mainly composed of *Microvelia douglasi*, was higher in planted sections of experimental rice fields ($p < 0.001$). In Coleoptera, only larval *Guinotus* spp. were more prevalent in unplanted sections, and for adults of this species and for other Dytiscidae, no differences were found ($p < 0.05$).

The variety of insect fauna at MD in tall and short rice sections was poorer than that at AN, and almost all densities of insects were lower at MD. Gerridae and Dytiscidae other than *Guignotus* spp. were not collected at MD. No significant difference in density was detected for any insects between the two sections ($p < 0.05$) (Table 4).

DISCUSSION

Our finding that *C. tritaeniorhynchus* larvae were more abundant in rice fields with greater open water surface area and less canopied by rice plants, agrees with observations made by Makiya (1967), Reuben (1971) and Mogi (1978) all of whom reported reduction of larval density of *C. tritaeniorhynchus* after rice matured, and the water surface was densely canopied. A variety of rice field breeding *Anopheles*, such as *A. gambiae*, *A. pharoensis*, *A. ziemanni*, *A. culicifacies*, *A. subpictus* and *A. quadrimaculatus*, also show a higher density during the early stages of rice growth (Russell and Rao, 1940, 1942; Chandler and Highton, 1975, 1976; Chambers et al., 1979; Snow, 1983; Prasad et al., 1990), and the same tendency for *A. sinensis* was first revealed in this study.

Oviposition preference of females, positive movement to the open water surface by larvae and selective predation and mortality are possible causes for the higher density of these mosquitoes in the open water side. Evaluation of these possible causes was not performed but biased distribution of young instars toward the open water surface, which perhaps reflects the local distribution of eggs, suggests that this local difference in mosquito larval density is due to the oviposition preference by females to open water surfaces which was proposed by RUSSELL and RAO (1942), SEN (1948), REUBEN (1971), and PRASAD et al. (1990), all of whom stressed mechanical obstruction to oviposition in a rice field with dense and tall plants. Covering by plants may affect oviposition not only by mechanical obstruction but also by differences in the light conditions and water temperature. The attractive factors for oviposition of rice field mosquitoes must be studied in greater detail.

Spacial and temporal fluctuations in density were widely observed within a section. These are probably due to small sample size and water conditions of each section induced by past chemical treatments and other rice culturing practices in the different rice fields.

ACKNOWLEDGEMENTS

We are indebted to Prof. Yoshito WADA for his comments on the manuscript. We also thank the owners of the rice fields, who kindly agreed to long-term investigations on their land. Dr. Yoshio TSUDA provided helpful advice for the statistical analysis.

REFERENCES

CHAMBERS, D.M., C.D. STEELMAN and P.E. SCHILING (1979) Mosquito species and densities in Louisiana ricelands. *Mosq. News* **39**: 658–668.

CHANDLER, J.A. and R.B. HIGHTON (1975) The succession of mosquito species (Diptera: Culicidae) in rice fields in the Kisumu area of Kenya, and their possible control. *Bull. Entomol. Res.* **65**: 295–302.

CHANDLER, J.A. and R.B. HIGHTON (1976) The breeding of *Anopheles gambiae* GILES (Diptera: Culicidae) in rice fields in the Kisumu area of Kenya. *J. Med. Entomol.* **13**: 211–215.

GARCIA, R., W.G. VOIGHT, A.E. COLWELL, A.K. NOMURA, D.L. WOODWARD and N.L. ANDERSON (1992) Relationship between flowering of wild rice and larval mosquito (Diptera: Culicidae) abundance in California. *Environ. Entomol.* **21**: 1294–1300.

MAKIYA, K. (1967) Population dynamics of mosquitoes in Nagoya District. 1. Larval populations in a paddy field and irrigation ponds in 1967. *Jpn. J. Sanit. Zool.* **21**: 60–70.

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

PRASAD, R.N., S.N. SHARMA, K.J. VIRIK and V.P. SHARMA (1990) Anopheline breeding in paddy fields and its relationship to growth of plants. *Mosq.-Borne Dis. Bull.* **7**: 104–106.

REUBEN, R. (1971) Studies on the mosquitoes of North Arcot District, Madras State, India. 5. Breeding places of *Culex vishnui* group of species. *J. Med. Entomol.* **8**: 363–366.

RUSSEL, P.F. and T.R. RAO (1940) The anophelines of ricefields in south eastern Madras. *J. Malar. Inst. India* **3**: 427–446.

RUSSEL, P.F. and T.R. RAO (1942) On relation of mechanical obstruction and shade to ovipositing of *Anopheles culicifacies*. *J. Exp. Zool.* **91**: 303–329.

SEN, P. (1948) *Anopheles* breeding in the ricefields of lower Bengal: Its relation with the cultural practices and with the growth of rice plants. *Indian J. Malar.* **2**: 221–237.

SNOW, W.F. (1983) Mosquito production and species succession from an area of irrigated rice fields in The Gambia, West Africa. *J. Trop. Med. Hyg.* **86**: 237–245.

SOKAL, R.R. and F.J. ROHLF (1981) *Biometry*, 2nd ed. Freeman, New York, pp. 1–859.

SURTEES, G., D.I.H. SIMPSON and E.T.W. BOWEN (1970) Rice field development and arbovirus epidemiology, Kano Plain, Kenya. *Trans. Roy. Soc. Trop. Med. Hyg.* **64**: 511–518.

TAKAGI, M., A. SUGIYAMA and K. MARUYAMA (1995) Effect of rice culturing practices on seasonal occurrence of *Culex tritaeniorhynchus* (Diptera: Culicidae) immatures in three different types of rice growing areas in central Japan. *J. Med. Entomol.* **32**: 112–118.