Tropical Medicine, 13 (4): 193−199, Dec., 1971

Ecology of Vector Mosquitoes of Japanese Encephalitis, Especially of *Culex tritaeniorhynchus summorosus*.

4. Development of Immature Stages of *Culex tritaeniorhynchus summorosus* with Particular Reference to Temperature in Spring and Autumn

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(Received for Publication November 22, 1971)

Abstract

Eggs of *Culex tritaeniorhynchus summorosus* laid by wild-caught and laboratory-colonized females were reared to adults under outdoor natural conditions particularly in spring and autumn, and the relation of the developmental period of immature stages of the mosquito to the extrinsic temperature was given. The results indicated that the developmental speed of immature stages given as the reciprocal of period decreases clearly with the drop of temperature and the development hardly occurs at the temperature below about 16°C.

Introduction

Overwintered females of *Culex tritaeniorhynchus summorosus* emerge to feed on animals early in spring in the Nagasaki area (Omori et al., 1965; Wada et al., 1967), but the first appearance date differs from year to year probably by the prevailing temperatures. The date for the emergence as adults of new generation will be influenced by the appearance date of overwintered females and the

* Contribution No. 196 from the Department of Medical Zoology, Nagasaki University School of Medicine.

temperatures during immature stages of mosquitoes derived from them. Also, the emergence of adults in autumn will be limited by lowering temperatures. In this connection, the knowledge on the developmental periods of immature satges at various temperatures help us to understand the ecology of this mosquito in spring and autumn. For this reason, eggs of *C. t. summorosus* laid by wild-caught and laboratory-colonized females were reared to adults under outdoor natural conditions particularly in spring and autumn, and the relation between the extrinsic temperature and the developmental period of immature stages of the mosquito was examined; these results which will be given in this paper are also useful for the ecological study of this mosquito during active breeding season.

Material and Method

Overwintered females of *Culex tritaeniorhynchns summorosus* immediately after blood feeding were collected at animal sheds in the Nagasaki area from early spring in 1966 and 1967, and kept with 2% sugar solution at an outdoor insectary of the Department of Medical Zoology, Nagasaki University School of Medicine for oviposition, and egg rafts laid were separately reared to adults with equally mixed powder of Ebios (brewer's yeast) and mouse pellets. Also eggs laid at the artificial conditions of 27°C and 14 hour daily photoperiod by females of the laboratory colony were reared to adults in 1966 by the same method at the outdoor insectary.

The periods of eggs, larvae or pupae change considerably from individual to individual particularly at low temperatures even when they are reared concurrently from one egg raft. As the time-curve of hatching, pupation, or emergence is usually skewed toward right, the egg, larval, or pupal period is considered to be represented better by the median or the earliest individual rather than by taking arithmetic mean. In the present experiments the earliest individual was used for convenience, and the dates were recorded for hatching, pupation, or emergence when the first individual appeared.

Results obtained

Dates are given in Table 1 for feeding, oviposition, hatching, pupation, and emergence of *C. t. summorosus* under natural conditions of the outdoor insectary of the Department of Medical Zoology in 1966 and 1967. Here, the feeding date means that of the collection of the females just after blood feeding in animal sheds.

In 1966, the overwintered freshly-fed females were collected on March 4, March 13 and April 3 and kept under natural conditions for oviposition. Eggs laid by them were reared to adults as shown in Table 1. The dates of oviposition ranged from March 16 to April 12, and those of adult emergence from April

30 to May 5. It is interesting that the difference of the emergence dates was only 5 days which was much shorter than the difference of oviposition dates, 27 days. The same tendency was observed also in 1967; the difference for oviposition was 11 days from April 13 to April 24, and that for emergence was 5 days from May 10 to May 15. These facts are thought to be explained by the slower development of immature stages of mosquitoes at the lower temperature earlier in spring.

In summer the developmental period is, of course, shorter than in spring due most probably to higher temperature; for example, the larvae which had hatched on August 10, 1966 pupated in five days and then emerged as adults in one day. Having become later in season, the developmental period of immature stages became gradually longer, and

Table 1. Development of immature stages of *Culex tritaeniorhynhus summorosus* under outdoor natural conditions, 1966 and 1967, Nagasaki.

Feeding	Oviposition	Hatchihg	Pupation	Emergence
1966				
Mar. 4	Mar. 16	Mar. 23	Apr. 26	Apr. 30
Mar. 4	Apr. 4	Apr. 11	May 2	May 5
Mar. 13	Apr. 4	Apr. 11	May 2	May 5
Mar. 13	Apr. 9	Apr. 17	May 2	May 5
Apr. 3	Apr. 12	Apr. 19	May 2	May 4
(1)	May 13	May 15	May 25	May 27
(1)	May 16	May 18	May 30	Jun. 2
(2), (3)		Aug. 10	Aug. 15	Aug. 16
(1), (3)	Aug. 24	Aug. 25	Aug. 30	Aug. 31
(2), (3)		Sep. 9	Sep. 14	Sep. 16
(2), (3)		Sep. 15	Sep. 25	Sep. 28
(2), (3)		Sep. 26	Oct. 7	Oct. 8
(2), (3)		Oct. 12	Oct. 27	Oct. 31
(2), (3)		Nov. 2	unable to pupate	
(2), (3)		Nov. 28	unable to pupate	
1967				
Mar. 30	Apr. 14	Apr. 19	May 8	May 11
Mar. 30	Apr. 18	Apr. 22	May 10	May 13
Mar. 30	Apr. 24	Apr. 27	May 12	May 15
Apr. 1	Apr. 13	Apr. 17	May 9	May 11
Apr. 1	Apr. 19	Apr. 23	May 9	May 11
Apr. 10	Apr. 19	Apr. 23	May 8	May 10
Apr. 10	Apr. 20	Apr. 24	May 8	May 10
Apr. 10	Apr. 21	Apr. 24	May 10	May 13

(1) Eggs ovipositd in the laboratory of 27°C were placed at the outdoor insectary.
(2) First instar larvae immediately after hatching in the laboratory of 27°C were placed at the outdoor insectary.
(3) Data from Kawai (1969), Table 13.

finally the larvae which had hatched after the beginning of November were unable to pupate.

Since in the above the negative correlation between the developmental period of immature stages of *C. t. summorosus* and the mean of extrinsic temperatures was thought to exist, the data were arranged in Figs. 1, 2, 3, and 4 to show respectively the more detailed relations between

FIG. 1

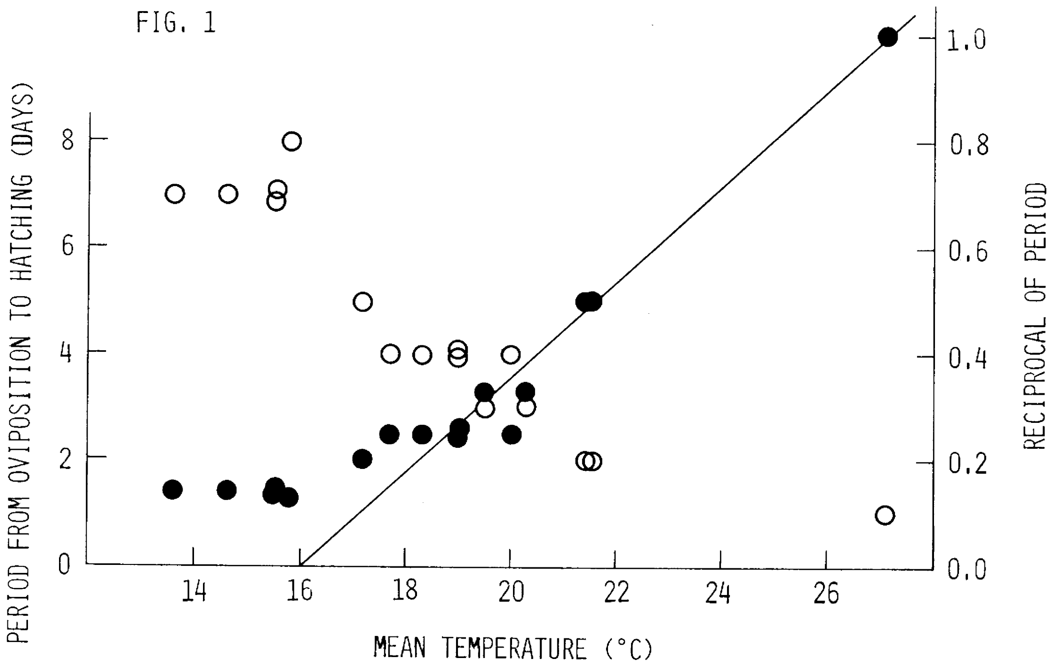
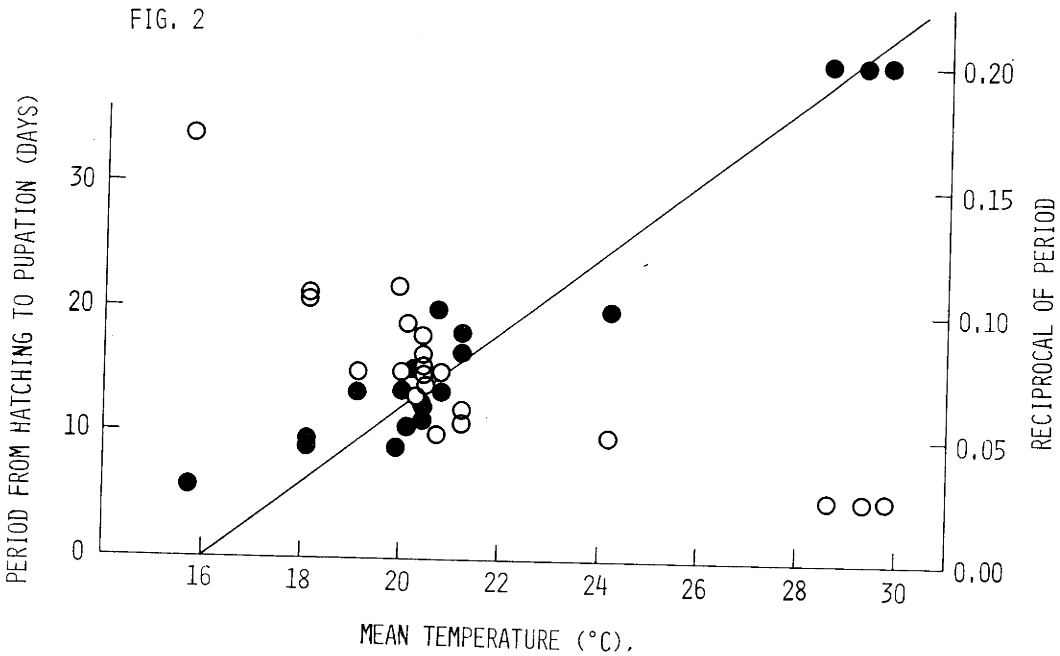
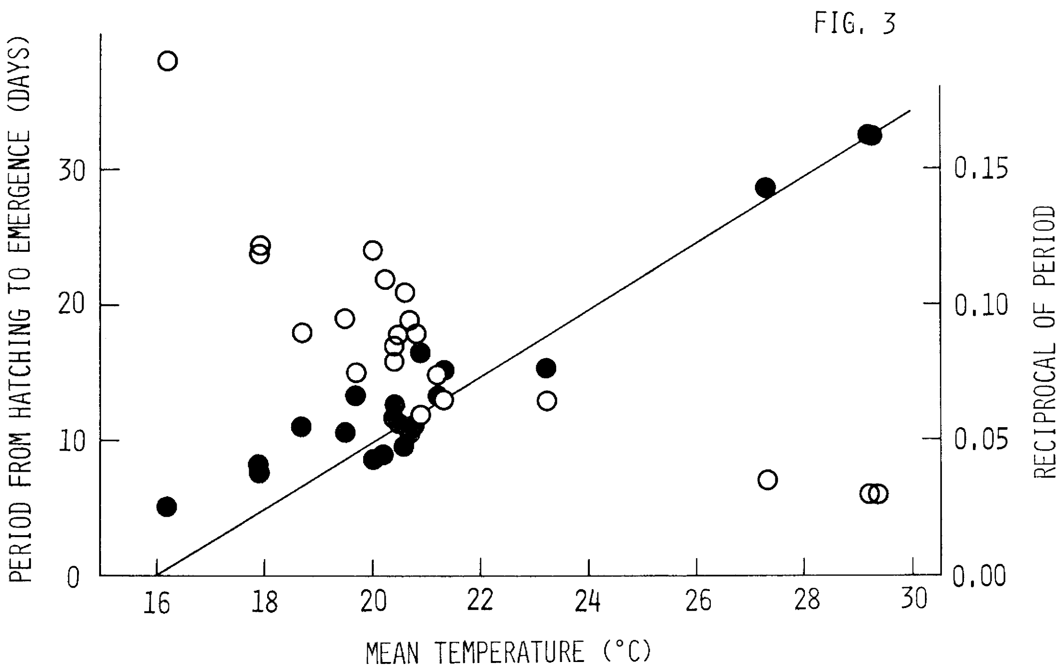
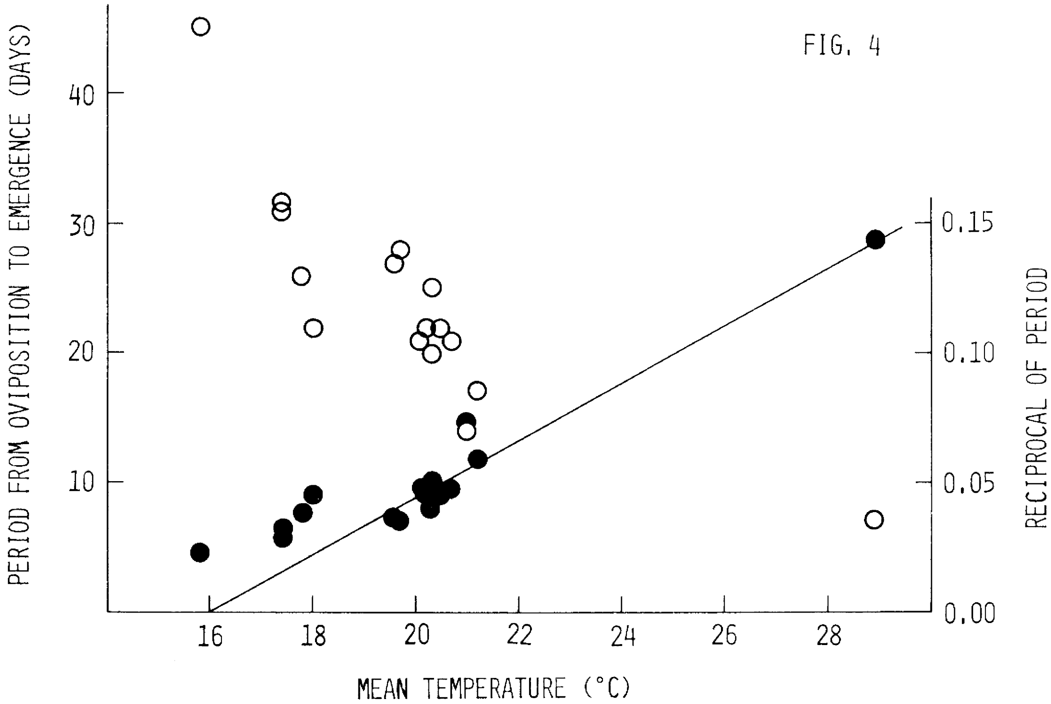


FIG. 2







Figs. 1—4. Relation of the developmental period (white circle) and the developmental speed given as the reciprocal of the period (black circle) of immature stages of *Culex tritaeniorhynchus summorosus* to the mean of extrinsic temperatures at the outdoor insectary. Fig. 1, the egg stage (from oviposition to hatching); Fig. 2, the larval stage (from hatching to pupation); Fig. 3, the larval and pupal stage (from hatching to emergence); Fig. 4, the egg, larval and pupal stage (from oviposition to emergence). The cases in which the first instar larvae just after hatching were placed at the insectary (see Table 1) are not included in Figs. 1 and 4.

the means of extrinsic temperatures and the periods from oviposition to hatching, from hatching to pupation, from hatching to emergence, and from oviposition to emergence. In these figures, reciprocals of developmental periods in days were also given to show developmental speeds. In all cases it was clearly shown that the lower the temperature is, the longer the developmental period is, and the relation between the two appears to be shown by rectangular hyperbola. As expected from the nature of rectangular hyperbola, developmental speeds represented by reciprocals of periods in days are shown to be linear to temperatures in the range higher than about 19°C, and the line crosses the temperature-axis at approximately 16°C. This means that at temperatures of about 16°C the development of immature stages scarcely occurs. However, the development does occurs slowly at mean temperatures around 16°C or even lower, as indicated in the figures. This seems due largely to the fact that the mosquitoes were reared under outdoor natural conditions with fluctuating temperatures. Even when the mean temperature for the period of a stage or stages is slightly lower than 16°C, the temperature in some part of the period is probably higher than 16°C and accordingly the development is expected.

In the experiments mentioned above, mosquitoes were reared under favorable conditions in respect of food and density in the larval stage. If the food had insufficiently been given, the developmental period would have been prolonged. In paddy-fields, which are the main breeding place of *C. t. summorosus* in Japan, the water is usually of lower organic matter content and therefore the longer developmental period is expected, than in the present experiments.

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日本脳炎伝搬蚊，特にコガタアカイエカの生態

4．コガタアカイエカの未成熟期の発育と特に春と秋における温度との関係

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摘　　要

野外で採集した，または実験室で累代飼育中のコガタアカイエカ雌成虫が産んだ卵を，屋外飼育室の自然条件下で特に春及び秋に成虫にでま飼育して，温度と未成熟期の発育期間との関係を求めた．その結果，発育日数の逆数として求めた発育速度は，温度の低下と共に顕著におそくなり，約 16℃以下では殆んど発育しないことがわかった．