THE INFLUENCE OF TEMPERATURE AND RELATIVE HUMIDITY UPON THE DEVELOPMENT OF THE EGGS OF FRUIT TREE RED SPIDER MITE *METATETRANYCHUS ULMI* (KOCH)

(Acarina: Tetranychidae)

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In Japan after World War II, the so-called red mite has become rampant on the fruit trees, the vegetables and forest nurseries, but no suitable measure of control has been established. Though ecological study is fundamental to the control, the ecology of Tetranychidae has been studied very little. Newcomer & Yothers (1929) and Blair & Groves (1950) have worked with *Metatetranychus ulmi* (KOCH), Bodenheimer (1951) with *Ancychus orientalis* ZACH and *Epitetranychus althaeae* V. HANST., English & Turnipseed (1941) with *Paratetranychus citri* MCGREGOR and Fukuda & Shinkaji (1954) with *Metatetranychus citri* MCGREGOR. However, the above researchers, except Bodenheimer, Fukuda & Shinkaji, have not touched upon the problem of the humidity which exerts much influence on the development of the egg. The humidity and the temperature have been recognized to be the main factors which control the population of mites in the field. The author has made experimental studies on the effect of the humidity and the temperature on the development of the egg of fruit tree red spider mite which does serious damage in northern Japan.

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Methods

Adult female of *M. ulmi* were collected early in June, 1956, from apple trees in the experimental orchard of the Faculty of Agriculture, Hokkaido University. They were reared on a little vinyl sheet which was kept floating on the water to prevent their escape. They were divided into several groups and were kept separately in the thermostat which was regulated at the desired temperatures. The eggs were all summer eggs (non-diapause eggs)*. In order to provide the eggs at the same stage of the development, those which were laid within 12 hours were used. The regulation of humidity was done by Zwölfer's method: viz., 6 humidity series were prepared with saturated solutions of $ZnCl_2$, $CaCl_2$, $Ca(NO_3)_2$, NaCl, KNO_3, and H_2O respectively. Next, the above series were put in 7 different thermostats, which were kept at 15°, 20°, 23°, 25°, 27°, 30° and 35°C respectively. Therefore, there were 42 experimental series in total. Each series contained about 100 eggs. The eggs were examined daily at a definite time under the microscope, particular attention being paid for the hatching of the egg.

Experimental

HATCHING RATIO. Table I shows the result of the observation on the hatching under various conditions of temperature-humidity. The temperature for the hatching ranges from 15°C to 30°C, and the humidity from 28% to 100%.

In these experimental series the high hatching ratio is obtained only at the temperatures ranging from 15°C to 30°C in the NaCl (r. h. 72–77%) series and KNO_3 (r. h. 90–94%) series, and from 15°C to 23°C

TABLE I. Hatching ratio (%) of *Metatetranychus ulmi* under various conditions of temperature-humidity.

°C \ r. h. (%)	$ZnCl_2$ (17)	$CaCl_2$ (28-33)	$Ca(NO_3)_2$ (49-57)	NaCl (72-77)	KNO_3 (90-94)	H_2O (100)
35	0	0	0	0	0	0
30	0	0	62	90	94	50
27	0	3	74	92	91	66
25	0	8	81	94	92	84
23	0	10	82	95	95	90
20	0	13	84	94	95	97
15	0	0	63	96	93	98

* LEES (1953) has used *M. ulmi* as his material and treated the relation between photoperiod and diapaused. He suggests that the turing point from diapause to non-diapause occurs in the photoperiod of 14–15 hours. In Sapporo the daily photoperiod at the beginning of July is 15 hours and the mite lays only summer eggs.

in the H_2O (r. h. 100%) series. In the series in which the humidity is lower than $Ca(NO_3)_2$ series, no one shows the hatching ratio higher than 90%. In $ZnCl_2$ (r. h. 17%) series no hatching takes place.

RATIO FOR THE COMPLETION OF EMBRYONIC DEVELOPMENT. An experiment has been done to ascertain the ratio for the completion of embryonic development. The ratio is given as follows:

$$\frac{\text{Number of hatched eggs} + \begin{array}{c}\text{Number of unhatched eggs}\\ \text{but with perfect embryo}\end{array}}{\text{Total number of eggs}} \times 100\%$$

TABLE II. Ratio for the completion of embryonic development of *M. ulmi* under various conditions of temperature-humidity.

C° \ r. h. (%)	$ZnCl_2$ (17)	$CaCl_2$ (28-33)	$Ca(NO_3)_2$ (49-57)	NaCl (72-77)	KNO_3 (90-94)	H_2O (100)
35	0	0	0	0	0	0
30	0	8	90	92	99	87
27	0	55	93	93	95	94
25	0	70	99	100	95	96
23	24	78	94	98	97	96
20	48	87	91	95	96	100
15	0	22	87	100	94	100

According to the above table, the range of the humidity and the temperature changes which bring about the perfection of the embryonic development is far wider than those for the hatching. The ranges in these series are; the 20°C and 23°C seri. of $ZnCl_2$ (r. h. 17%) and the 15°C and 30°C seri. of $CaCl_2$ (r. h. 28–32%). In other 7 series [the 20°C seri. of $CaCl_2$ (r. h. 32%) and the 15°–30°C seri. of $Ca(NO_3)_2$ (r. h. 49–57 %)] the ratio goes up beyond 85%, proving that the R. C. E. D.* is higher than the H. R.** Even in the 27°C and 30°C seri. of H_2O (r. h. 100%) where the hatching ratio ranges only from 50% to 60%, the embryos grow up with higher ratio than 85%. Thus it can be concluded from the above, that in the early developing stage the embryo in the egg adapts much more easily to the enviromental temperature and humidity than in the later. Moreover in the two series of NaCl (r. h. 72–77%) and those of KNO_3 (r. h. 90–94%), the R. C. E. D. and H. R. coincid with each other to some extent; probably in those series nearly

* Ratio of completion of embryonic development.

** Hatching ratio.

TABLE III. The egg period and developmental speed of *M. ulmi* under various conditions of temperature-humidity.

°C	r. h. (%)	Egg period (day) Max.	Min.	Average	Developmental speed
35	100	∞	∞	∞	0
	90	∞	∞	∞	0
	72	∞	∞	∞	0
	49	∞	∞	∞	0
	28	∞	∞	∞	0
	17	∞	∞	∞	0
30	100	6	5	5.67	0.1764
	91	6	4	4.96	0.2016
	73	7	4	5.15	0.1942
	52	6	5	5.56	0.1799
	30	∞	∞	∞	0
	17	∞	∞	∞	0
27	100	6	5	5.54	0.1804
	92	6	4	4.95	0.2020
	73	6	4	4.97	0.2011
	53	6	4	5.17	0.1983
	31	7	5	6.62	0.1511
	17	∞	∞	∞	0
25	100	7	5	6.19	0.1617
	92	6	5	5.37	0.1862
	74	6	5	5.29	0.1890
	53	7	5	5.60	0.1786
	31	8	7	7.50	0.1333
	17	∞	∞	∞	0
23	100	8	6	7.05	0.1418
	92	7	6	6.20	0.1613
	74	7	5	6.37	0.1571
	54	7	6	6.77	0.1478
	32	8	8	8.00	0.1250
	17	∞	∞	∞	0
20	100	9	8	8.10	0.1235
	93	10	8	8.15	0.1227
	75	9	8	8.10	0.1235
	55	9	8	8.25	0.1212
	32	10	10	10.00	0.1000
	17	∞	∞	∞	0
15	100	15	13	13.73	0.0728
	94	16	13	14.43	0.0693
	77	17	13	14.54	0.0688
	57	18	14	15.42	0.0649
	33	∞	∞	∞	0
	17	∞	∞	∞	0

all of the embryo hatch out. At 35°C over-all death of the egg takes place at any humidity without the completion of the embryo.

THE RELATION BETWEEN THE FGG PERIOD AND TEMPERATURE-HUMIDITY The egg period and the developmental speed (given as the reciprocal of the egg period) at various temperatures and humidities are shown in Table III.

Looking over the above table one will understand that the shortest egg period through the whole experiments is seen in the KNO_3 series (r. h. 92%) kept at 27°C for 4.95 days in average. The next shortest one is 4.96 days of the KNO_3 series (r. h. 91%) at 30°C in which the egg period uniformly needs a little longer time at any humidity than in the 27°C series. Generally speaking among the 4 temperature series of 30°, 27°, 25°C and 23°C, the NaCl (r. h. 73–74%), and KNO_3 (r. h. 91–92%) are the shortest and the $Ca(NO_3)_2$ (r. h. 52-54%) is the next shortest. In the highly humid H_2O (r. h. 100%) and dry $CaCl_2$ (r. h. 28–33%) series the egg takes considerably longer time for hatching than in moderately humid series. In 20°C series, there is no remarkable difference of the times required for hatching by the H_2O (r. h. 100%), KNO_3 (r. h. 93%), NaCl (r. h. 75%) and $Ca(NO_3)_2$ (r. h. 55%) seri.; they take respectively 8.10, 8.15, 8.10 and 8.25 days. In 15°C series, if higher humidity exists, the mean egg period becomes shorter. In H_2O series it takes 13.73 days. The fact is interesting, as mentioned before, showing that in the very high humid series with low temperature the eggs hatch with high ratio.

Discussion

The thermohygrograms showing the contour curve for each of R. C. E. D. and H. R. are given as Fig. I and Fig. II. From the figures it becomes clear, first that the temperature for the hatching ranges from lower than 15°C (theoretically the development threshold is 9.03 °C as will be mentioned later) to 33°C; and the relative humidity from 28% to 100%. Secondly, it is clear that the best condition for the hatching is confined to the temperature between 15°C or lower and 31°C, and to the relative humidity between 65% and 100% (the hatching reaches above 90%). Thirdly, the effective conditions for the completion of the embryo in the shell include the temperature which stretches from lower than 15°C to 34°C and relative humidity from 15% to 100%. Lastly, the condition which produces embryo above 90

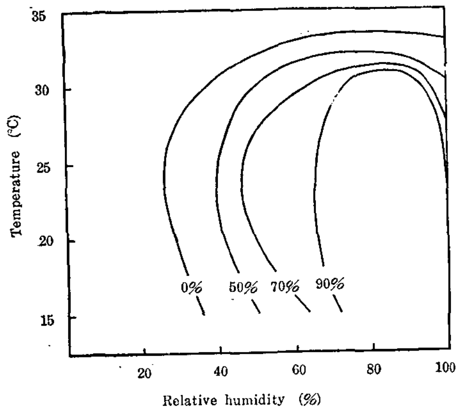

Fig. I. Thermohygrogram for hatching of *M. ulmi*

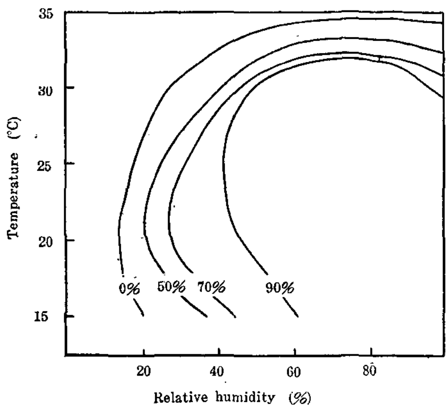

Fig. II. Thermohygrogram for completion of embryonic development of *M. ulmi.*

% is gained between the temperature lower than 15°C and 32°C; and between the relative humidity 43% and 100%. The sensibility to the temperature and the humidity of the developing embryo is different from that of the hatching embryo. The former is more resistant than the latter.

For the oriental red mite in Palestine, the conditions which comprise 24°–25°C temp., and 63–64% r. h. is most effective, and for the common red mite, 25°–26°C temp., and 63–69% r.h. (Bodenheimer, 1951). For the citrus red mite in Shizuoka Prefecture (central district of Japan), it is at 25°–26°C with 60–70% r. h. In the case of fruit tree red spider mite the author found, on the other hand, the effective temperature and humidity ranges 22°–23°C and 80–90% r. h. for hatching as shown in Fig. I. The temperature is lower and the humidity is higher than in the other species. The difference between this species and citrus red mite is seen in the effective temperature which is lower in the former than in the latter. This agrees with the fact that the citrus red mite is a southern variety while the present mite is a northern one as seen from their distribution in Japan.

Next, let the effect of the temperature and the humidity on the speed of embryonic development be considered. As Table III shows, the period required for the development becomes shorter in accordance with the rising of the temperature under 27°C regardless of the other conditional differences existing in the experimental series. The law of total effective temperature as indicated in Fig III is applicable for

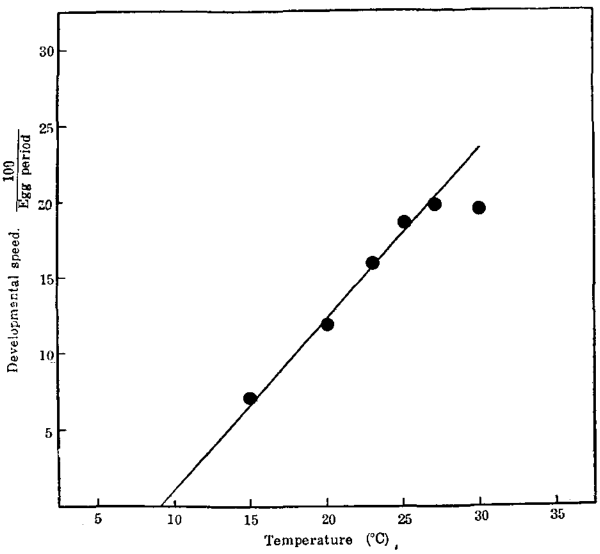

Fig. III. Showing the relationship between temperature and the developmental speed of the egg of *M. ulmi.*

the mean value of the developmental speed obtained from several temperature series in series of KNO_3 and in that of NaCl. The law is not applicable for 30°C. The temperature 30°C might be beyond the range within which the law is valid. The threshold of the development can be gotten by prolonging the straight line in the figure. From the value of the threshold it can be seen that theoretically the embryo cannot be raised at a temperature lower than 9.03°C. However the prolonged line is merely theoretical. Practically the line curves at both ends in the form of an "S", and so it is highly probable that the real threshold exists somewhere at a lower point than the theoretical.

Newcomer & Yothers (1929) have studied the egg period of *M. ulmi* for several generations, and reported that it ranges 7.71–19.0 days, on an average 9.93–10.83 days. Blair & Groves (1950) have reported that the egg period is 8.2–12.1 days, the third and fourth generation being the shortest. According to Cagle (1946) the relationship between temperature and the egg period is shown as the following formula

$$Y = 749.9\,(2.71828 - 0.065\,X)^{*}$$

The research has been done at inconstant temperatures set up in

* Y = egg period X = temp. °F

the laboratory and also under the similar condition in the field. Miller (1953) has studied the egg period at a constant temperature as well as at inconstant, and observed that the period becomes longer at the constant temperature than at the inconstant. For example, the egg period at 69.9°F which is the mean valve of inconstant varying temperature, Miller found to be 8.9 days; while at constant 70°F, it is 10.0 days. There is a little difference between the egg period of Tasmanian *M. ulmi* determined by Miller and that of Hokkaido determined by the present author. Namely, it is remarkably longer in the former than in the latter. This difference might in all probability be a result from the geographical variation.

At any rate, within the limits of normal development, the higher the temperature of the enviroment, the shorter the egg period becomes; at 27°C it is reduced by half of that at 20°C. So far as the egg period is concerned, the temperature is the most important element which controls the biotic potentiality.

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