INFLUENCE OF TEMPERATURE ON THE LIFE-HISTORY PARAMETERS OF THE YELLOW GRAPE-VINE MITE *EOTETRANYCHUS CARPINI* (OUDEMANS) (ACARI: TETRANYCHIDAE)

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ABSTRACT - The life-history parameters of *Eotetranychus carpini* (Oudemans), a rarely studied species, were determined in the laboratory at five temperatures ranging from 15 ± 0.5^0 C to 30 ± 0.5^0 C (temperatures at the surface of the plant). Experiments were carried out in an air-conditioned room with relative humidity maintained at $60 \pm 10\%$, and a photoperiod of 16L/9D (illuminance 3,500 to 4,000 lx). The experimental conditions were monitored very precisely (thermocouple for temperature, electronic hygrometer for relative humidity, and a silicon detector for illuminance).

The total development time decreased from 28.4 days to 9.7 days as the temperature increased from 15.0 to 30.3°C. There was no significant difference between the development times at 26.0 and 30.3°C. The lower thermal threshold of development was calculated to be 7 ± 1^0 C. Mean daily oviposition increased with temperature between 15.0 and 30.3^0 C. The maximum value of 3.2 eggs per day was obtained between 26.0 and 30.3^0 C. The intrinsic rate of natural increase (r_m), which ranged from 0.058 to 0.153, rose between 15.0 and 26.0^0 C and then decreased at 30.3^0 C. The maximum r_m value (0.153) was obtained at 26.0^0 C, which can be assumed to be approximately the optimum temperature for *E. carpini*.

INTRODUCTION

The phytophagous mite *Eotetranychus carpini* (Oudemans) is present in all the vineyards of southern Europe and North Africa. It poses serious problems to vine growers when there are large outbreaks, but little is known about its life cycle. Although the first observations of outbreaks were made some time ago (Rambier, 1958), except for some field observations by Mathys and Tencalla (1960), nothing is known in the literature on the life-history parameters of *E. carpini*.

In the present study we characterize the main life-history parameters of a population of the mite, as defined by Birch (1948), at 5 temperatures: 15.0, 19.8, 22.7, 26.0 and 30.3^0 C. Following the works of Saito and Suzuki (1987), it appeared essential to monitor the experimental conditions as accurately as possible, particularly temperature, so that conditions reported were accurate.

Saito and Suzuki (1987) have studied temperature variations between the leaf surface, where the mites live, and the ambient (1 cm above the leaf surface). They found that temperatures of live leaf surfaces were not different from the ambient, but that temperature of detached leaves on wet substrates were always lower than the ambient. Depending on rearing techniques, the use of wet substrates may cause a temperature difference of about 3^0 C. Differences in leaf surface temperatures directly affect mite development. Without this information it is difficult to compare data obtained with different rearing techniques.

MATERIALS AND METHODS

Mite breeding; host-plant cultivation - All experiments were carried out using descendents of ten females taken from an experimental vineyard located in Montpellier (France). Apart from several fungicidal treatments using sulfur and Bordeaux mixture, no acaricide or insecticide had been applied.

Mites were raised in an air-conditioned room (25 ± 2^0 C, $60 \pm 10\%$ RH, 16L/9D at 4,000 lx) on the same host plant (*Vitis vinifera* L., Syrah variety) using the method of detached leaves, which were taken from 2-year old

plants grown in pots in a greenhouse, and placed on water-soaked cotton. Mites were raised on the underside of the leaves.

Experimental conditions - Temperature was measured at the leaf surface in each experiment, using a thermocouple (copper-constantan) connected to a digital multimeter (Keithley No. 197) accurate to within a microvolt. We found noticeable differences between leaf surface and ambient temperatures. In the room at 15^0 C, the ambient mean temperature (= a t) measured 1 cm above the leaf surface was 15.5 ± 1.3^0 C and the leaf surface mean temperature (= l s t) 15.0 ± 0.6^0 C. Similarly, in the room at 20^0 C, a t was 20.6 ± 2.4^0 C and l s t 19.8 ± 0.9^0 C; in the room at 25^0 C, a t was 23.0 ± 3.6^0 C and l s t 22.7 ± 3.0^0 C; in the room at 30^0 C a t was 26.8 ± 1.5^0 C and l s t 26.0 ± 1.0^0 C; in the room at 35^0 C, a t was 32.5 ± 2.0^0 C and l s t 30.3 ± 2.0^0 C. In this study we used the leaf surface mean temperature as indicated in the tables. All experiments were carried out in air-conditioned rooms with relative humidity regulated at $60 \pm 10\%$, since this appears to favor mite growth (Bonato *et al.* in preparation). Lighting was provided by fluorescent tubes in a photoperiod of 16L/9D.The illuminance was 3,500 to 4,000 lx. This level was controlled using a silicon cell (MACAM SD 101 Q) connected to the multimeter and calibrated to the visible range.

Survival rate and development - Ten fertilized females from a breeding chamber were placed on leaf disks (4 cm^2). After 1 hour, the leaf disks with only one egg were kept. The females as well as excess eggs were killed to obtain one egg per disk. The eggs were monitored to determine the development and survival rate of the immature stages. Each individual was examined 3 times a day (at 7 a.m., 1 p.m., and 7 p.m.) and the transition from one stage to another was noted. The leaf disks were replaced every 2 days (at 26 and 30.3 ^{0} C) or every 5 to 6 days (at 15, 19.8 and 22.7^0 C). The number of eggs monitored at each temperature is indicated in Table 1.

Oviposition - One female teliochrysalis (C3) and two males were taken from the breeding chamber and placed on a leaf disk. Forty-eight hours after the female emerged, the males were killed. The date on which the female emerged was noted as well as the number of eggs laid per day. Disks were changed every 4 days.

Sex ratio - The sex ratio was determined at a single temperature, 19.8° C, which is the mean temperature during the vine growing period (from mid-April to mid-October). The method was the same as that used for oviposition, except that the females were placed on a new leaf disk every day and disks with eggs were maintained under the same experimental conditions (breeding conditions for the females). The sex ratio was determined on the basis of adults originating from the eggs.

Rate of population increase - The intrinsic rate of natural increase (r_m) defined by Birch (1948) is an index characterizing the maximum rate at which a population can increase under specific and constant environmental conditions, where neither space nor nourishment is limited and the cause of mortality can therefore only be physiological.

The net reproductive rate (R_O) is the sum of the $l_x m_x$ in the life tables. The mean generation time (T) is obtained here using the formula $T = \Sigma x l_x m_x / \Sigma l_x m_x$. The r_m is calculated from T and R_O using the formula $r_m = \text{Log } R_O/T$.

Table 1. Development times (in days) of immature stages and survival rates of *Eotetranychus carpini*.

Stage	15.0 ± 0.6°C	19.8 ± 0.9°C	22.7 ± 3.0°C	26.0 ± 1.0°C	30.3 ± 2.0°C
Eggs	11.9	6.3	5.0	3.8	3.6
Larva	3.3	1.7	1.7	1.3	1.9
Protochrysalis	2.2	1.0	0.9	0.8	0.6
Protonymph	2.8	1.5	1.2	1.1	1.1
Deutochrysalis	2.1	1.2	0.9	0.8	0.7
Deutonymph	3.4	2.2	1.3	1.3	1.2
Teliochrysalis	2.8	1.4	1.0	0.9	0.7
Total (Avg. ± S.E.)	28.4 ± 0.4	15.2 ± 0.2	12.0 ± 0.2	9.9 ± 0.1	9.7 ± 0.2
Number of eggs	32	32	32	31	40
Number of adults	25	22	22	22	19
Survival rate of immature stages (%)	78	69	69	71	48

RESULTS

Sex ratio - The proportion of females in 191 eggs laid by 8 females was 61.7%. This value was rounded off to 65% for the life-table calculations, but it is relatively low compared to results obtained by Wrensch and Young (1978) with other species.

Development: Survival rate of immature stages - The survival rate of immature stages at each temperature is shown in Table 1. The low values obtained in experiments carried out at 19.8, 22.7, and 26.0^0 C are probably not related to the breeding method. Rather than being extreme, these three temperatures were nearly optimal. A comparison with data obtained for other tetranychid mites (Gutierrez, 1976: Gotoh, 1987) showed that at these temperatures the expected mortality rate is around 20%, so we used the survival rate obtained at 15.0^0 C, i.e. 80%, to calculate the r_m corresponding to 19.8, 22.7, and 26.0^0 C.

Development time - The total development time decreased over the temperature range of 15.0 to 26.0^0 C. There was no significant difference between the total development times at 26.0 and 30.3^0 C, suggesting that the latter temperature is near the upper limit.

The lower thermal threshold for development (TD) was calculated by the ratio:

TD = a/b where a and b were determined by linear regression of the equation: DR = a + bt, where DR = the development rate, t = the temperature in ^{0} C, a = -0.0338, b = 0.0046 (r = 0.96). The TD was calculated to be 7 ± 1^0 C.

Oviposition and fecundity - The durations of preoviposition, oviposition, and postoviposition corresponding to each temperature are given in Table 2. Fecundities at 15.0, 22.7, and 30.3^0 C are shown in Figure 1. As the temperature rose from 15.0 to 30.3^0 C, the durations of preoviposition, oviposition, and postoviposition decreased, as did longevity (the differences were significant at p > 0.05, Student's t test).

Total fecundity and the mean number of eggs laid per day are given in Table 3. As the temperature rose from 15.0 to 26.0^0 C, total fecundity and the mean number of eggs laid per day increased. At 30.3^0 C, the mean number of eggs laid was the same as at 26.0^0 C (no significant difference at p > 0.05, Student's t test), but total fecundity was lower since oviposition did not last as long.

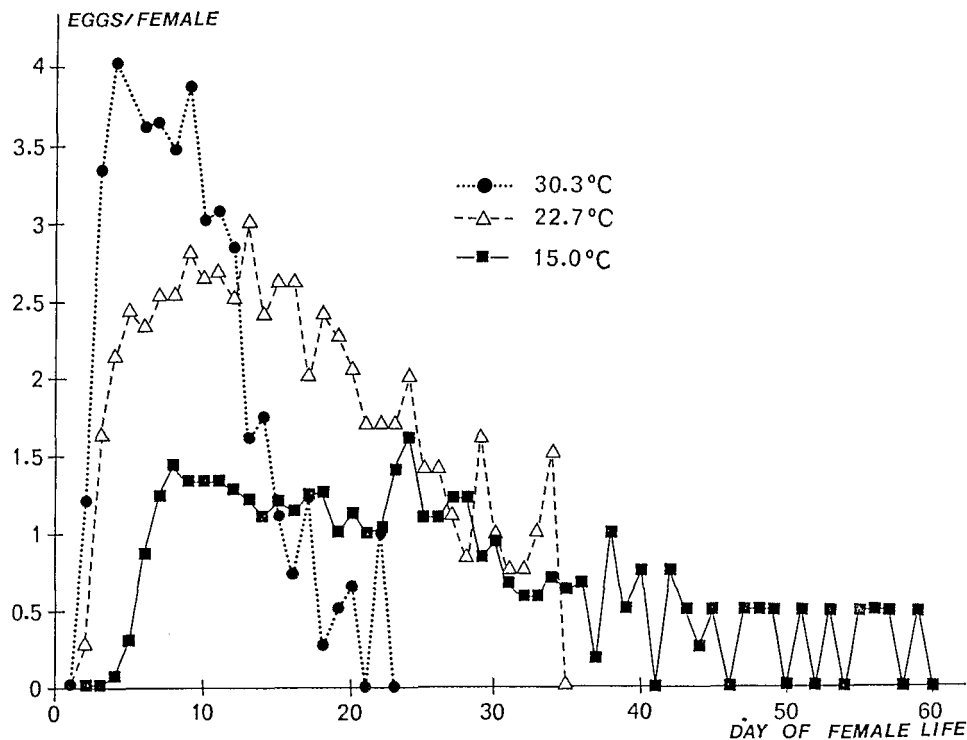**Rate of population increase** - The net reproduction rate (R_O) increased between 15.0 and 26.0^0 C (Table 4).

Fig. - Longevity and age- specific fecundity of *Eotetranychus carpini* females at 15.0^0 C, 22.7^0 C, and 30.3^0 C (60 $\pm10\%$ RH).

Table 2. Duration in days of various adult stages of *Eotetranychus carpini*.

	n	15.0 ± 0.6°C (Avg. ± S.E)	19.8 ± 0.9°C (Avg. ± S.E)	22.7 ± 3.0°C (Avg. ± S.E)	26.0 ± 1.0°C (Avg. ± S.E)	30.3 ± 2.0°C (Avg. ± S.E)
Preoviposition	31	5.4 ± 0.5	3.3 ± 0.2	1.9 ± 0.1	2.0 ± 0.1	1.3 ± 0.1
Oviposition	31	23.9 ± 2.0	21.2 ± 1.8	18.7 ± 1.3	14.8 ± 1.3	9.1 ± 0.9
Postoviposition	31	4.3 ± 1.7	1.9 ± 0.2	1.2 ± 0.1	1.2 ± 0.1	1.6 ± 0.2
Total adult longevity	31	33.6 ± 2.9	26.4 ± 1.8	21.9 ± 1.3	18.1 ± 1.3	12.1 ± 1.1

Table 3. Ovipositional rate of *Eotetranychus carpini*.

	n	15.0 ± 0.6°C (Avg. ± S.E)	19.8 ± 0.9°C (Avg. ± S.E)	22.7 ± 3.0°C (Avg. ± S.E)	26.0 ± 1.0°C (Avg. ± S.E)	30.3 ± 2.0°C (Avg. ± S.E)
Number of eggs laid per female	31	28.6 ± 1.9	33.2 ± 2.8	43.0 ± 2.9	46.4 ± 4.2	29.3 ± 2.8
Average number of eggs laid per day during oviposition period	31	1.3 ± 0.1	1.6 ± 0.1	2.4 ± 0.1	3.1 ± 0.1	3.2 ± 0.1

Table 4. Parameters related to potential rates of population increase of *Eotetranychus carpini*.

	15.0 ± 0.6°C	19.8 ± 0.9°C	22.7 ± 3.0°C	26.0 ± 1.0°C	30.3 ± 2.0°C
Net reproductive rate, R_O	14.92	17.17	22.04	23.76	9.48
Mean generation time, T in days	46.8	30.8	24.5	20.7	17.2
Intrinsic rate of natural increase, r_m in day-1	0.058	0.092	0.126	0.153	0.130
Finite rate of increase (λ)	1.059	1.096	1.134	1.165	1.138

It was lowest at 30.3^0 C since longevity was shortest at this temperature and mortality highest. The mean generation time (T) decreased as the temperature increased from 15.0 to 30.3^0 C. The intrinsic rate of natural increase (r_m) and the finite rate of increase (λ) rose between 15.0 and 26.0^0 C, where they reached their maximum. They decreased at 30.3^0 C, since R_O was lowest at this temperature (9.48) and mortality was highest (50%).

DISCUSSION AND CONCLUSION

In all poikilotherms, temperature affects the development time and fecundity, i.e., as temperature increases the development time decreases and more eggs are laid. *E. carpini* was no exception to this rule at temperatures ranging from 15.0 to 26.0^0 C, and its ideal temperature appeared to be around $26 ± 1^0$ C. Its lower temperature limit was $7 ± 1^0$ C, whereas the upper limit appeared to be above 30^0 C, probably about 32 to 33^0 C. These hypotheses were corroborated by the analyses of development times, fecundities, and intrinsic rates of natural increase.

The maximum r_m (0.153) seems rather low compared to the r_m of other tetranychid species, obtained at $25 ± 1^0$ C by different authors. Gotoh (1987) determined an r_m of 0.198 for *Eotetranychus uncatus* Garman and 0.178 for *Eotetranychus tiliarium* (Hermann) raised on *Alnus japonica* (Thunb.). Nickel (1960) found an r_m of 0.290 for *Tetranychus desertorum* Banks. Gutierrez (1976) reported 0.260 for *Tetranychus neocaledonicus* Andre, and Carey and Bradley (1982) obtained 0.203 for *Tetranychus turkestani* Ugarov and Nikolski, 0.219 for *Tetranychus urticae* Koch, and 0.207 for *Tetranychus pacificus* McGregor. However, it is difficult to compare these r_m values because many works do not take into

account all the data that must be included in the calculation (such as survival of the egg to the adult stage) and the method of calculating the r_m value is often not defined. Moreover, according to Saito and Suzuki (1987), rarely are the experimental conditions completely defined, controlled, and consistent. Life-history data obtained by various authors in different regions and by different methods were generally influenced by many factors which caused much variation. However variations due to differing methods are not inevitable, and efforts should therefore be made to reduce them (Saito and Suzuku, 1987).

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